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FOR THE
Promotion of Engineering Education.

PROCEEDINGS
OF THE
FOURTH ANNUAL MEETING,
HELD IN

BUFFALO, N. Y., AUGUST 20, 21, 22, 1896.

Volume IV.

EDITED BY
HENRY T. EDDY, C. FRANK ALLEN,
Committee.

PUBLISHED BY THE SOCIETY.
1897.

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THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION has completed four years of successful progress. It has been customary for many years for engineers to meet for the interchange of opinion and the benefits of personal association. The meetings of the Section of Engineering Education of the Congress of Engineering in 1893 resulted in the establishment of a permanent organization with a view to securing for engineering instruction the advantages derived from existing societies by other branches of the engineering profession. No form of education has taken a stronger hold upon the public or has developed so rapidly and successfully in the last third of a century as has engineering education. It inculcates earnestness, thoroughness and accuracy in the student in a pre-eminent degree. The spirit which pervades engineering colleges can properly be expected to secure superior results, not merely by virtue of the subjects taught, but also by improving the quality of teaching, perfecting the methods of presentation, and adapting means to ends in instruction as has been done in engineering. It is the purpose of the Society to aid in bringing about this result. The work of teaching engineering subjects is sufficiently new, so that much

saving will result in teaching, as in engineering, if the experience on the part of one shall prevent needless experimenting on the part of many. The meetings of this Society have already been found of definite value in this direction. The Society now numbers two hundred and three members, representing thirty-six states, Canada and several European countries. All who are engaged in the work of engineering education in any branch, or who have a special interest in it, are welcomed as members. The Fifth Annual Meeting will be held in Toronto, Ontario, August 16, 17, 18, 1897. (The Meeting of the British Association for the Advancement of Science will open on the afternoon of August 18, 1897.)

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SHEPARDSON, GEORGE D.,... Minneapolis, Minn.	Professor of Electrical Engineering, University of Minnesota.....	1895
SHOLL, JACOB M.,..... Hobart, Ind.	Civil Engineer.....	1893
SMArt, JAMES H.,..... Lafayette, Ind.	President, Purdue University.....	1896
SMArt, RICHARD A.,..... Lafayette, Ind.	Instructor in Engineering Laboratory, Purdue University	1896
SMITH, HARRY E.,..... Minneapolis, Minn.	Assistant Professor of Mechanical Engi- neering, University of Minnesota	1895
SMITH, HERBERT S. S.,..... Princeton, N. J.	Assistant Professor of Civil Engineering, Princeton University	1894
SNOW, CHARLES H.,..... New York, N. Y.	Vice Dean, School of Civil Engineering, New York University	1895
SOLBERG, HALVOR C.,..... Brookings, S. Dak.	Professor of Mechanical Engineering, South Dakota Agricultural College....	1894
SPALDING, FREDERICK P.,... Ithaca, N. Y.,	Assistant Professor of Civil Engineering, Cornell University.....	1893

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
SPANGER, H. W., Philadelphia, Pa.	Professor of Mechanical Engineering, University of Pennsylvania.....	1893
SPERR, FREDERICK W., Houghton, Mich.	Professor of Civil and Mining Engineering, Michigan College of Mines.....	1896
SPRINGER, FRANK W., Minneapolis, Minn.	Instructor in Electrical Engineering, University of Minnesota	1896
STALEY, CADY,..... Cleveland, Ohio.	President, Case School of Applied Science	1894
STANWOOD, JAMES B.,..... Cincinnati, Ohio.	Director, Technical School of Cincinnati	1894
STEWART, CLINTON B.,..... Golden, Colo.	Professor of Civil Engineering, Colorado State School of Mines	1894
STOUT, OSCAR VAN P., Lincoln, Neb.	Associate Professor of Civil Engineering, University of Nebraska	1894
STRATTON, SAMUEL W., Chicago, Ill.	Associate Professor of Physics, University of Chicago	1893
SWAIN, GEORGE F.,..... Boston, Mass.	Professor of Civil Engineering, Massachusetts Institute of Technology.	1893
TALBOT, AETHUR N., Champaign, Ill.	Professor of Municipal Engineering, University of Illinois	1893
TAYLOR, WILLIAM D.,..... Baton Rouge, La.	Professor of Physics and Engineering, Louisiana State University	1894
THOMAS, ROBERT G., Charleston, S. C.	Professor of Mathematics and Engineering, South Carolina Military Academy.....	1894
THOENBUREG, CHARLES L.,... South Bethlehem, Pa.	Professor of Mathematics, Lehigh University.....	1894
THURSTON, ROBERT H., Ithaca, N. Y.	Director of Sibley College, Cornell University.....	1893
TIMMERMAN, AETHUR H.,... Rolla, Mo.	Professor of Physics, School of Mines and Metallurgy, University of Missouri ...	1894
TOWLE, WILLIAM M.,..... State College, Pa.	Assistant Professor of Practical Mechanics, Pennsylvania State College.....	1895
TRAMMEL, ROBERT J.,..... Auburn, Ala.	Instructor in Mechanical Department, Alabama Polytechnic Institute.....	1896
TURNEAURE, FREDERICK E., Madison, Wis.	Professor of Bridge and Hydraulic Engi- neering, University of Wisconsin	1894
TYLER, HARRY W.,..... Boston, Mass.	Professor of Mathematics, and Secretary, Massachusetts Institute of Technology	1894

NAME AND ADDRESS.	TITLE.	DATE OF MEMBERSHIP.
UNWIN, WM. CAWTHORNE,.. London, England.	Professor of Engineering, City and Guilds of London Central Institution	1893
VAN ORNUM, J. L.,..... St. Louis, Mo.	Instructor in Civil Engineering Washington University.....	1895
VEDDER, HERMAN K.,..... Agricultural College, Mich.	Professor of Mathematics and Civil Engi- neering, Michigan State Agricultural College.....	1894
VOIT, ERNST,..... Munich, Bavaria.	Professor of Physics and Electricity, Koenigliches Polytechnikum.....	1894
WADDELL, J. A. L.,..... Kansas City, Mo.	Consulting Bridge Engineer.....	1893
WADSWORTH, JOEL E.,..... Middletown, Conn.	Civil Engineer.....	1895
WADSWORTH, M. EDWARD, Houghton, Mich.	President, Michigan College of Mines.....	1895
WAGNER, JOHN R.,	Superintendent of Motive Power, D. S. & S. R. R.	1894
WALKER, ELTON D.,..... Schenectady, N. Y.	Instructor in Engineering, Union College.....	1895
WHIPPLE, GEORGE C.,..... Brooklyn, N. Y.	Biologist, Department of Public Works.....	1896
WHITE, GEORGE H.,..... Worcester, Mass.	Professor of Civil Engineering, Worcester Polytechnic Institute.....	1896
WHITNEY, NELSON O.,..... Madison, Wis.	Professor of Railway Engineering, University of Wisconsin	1893
WILCOX, RALPH M.,	Instructor in Civil Engineering, Lehigh University.....	1894
WILLETT, JAMES R.,	Architect, 434 Jackson Boulevard	1896
WILLIAMS, SYLVESTER N.,.. Mt. Vernon, Iowa.	Professor of Civil Engineering, Cornell College	1893
WILMORE, JOHN J.,..... Auburn, Ala.	Professor of Mechanical Engineering, Alabama Polytechnic Institute	1894
WING, CHARLES B.,	Professor of Structural Engineering, Leland Stanford Junior University ...	1895
WOODWARD, CALVIN M.,.... St. Louis, Mo.	Dean of Polytechnic Department, Washington University	1894
WOODWARD, ROBERT S.,..... New York, N. Y.	Professor of Mechanics, Columbia University.....	1893

Total number of Members, 203.

DISTRIBUTION OF MEMBERS.

Alabama	4	Michigan	7	Texas	1
California	4	Minnesota	14	Vermont	2
Colorado	4	Mississippi	1	Virginia	2
Connecticut	4	Missouri	10	West Virginia	3
Delaware	1	Nebraska	4	Wisconsin.....	7
Idaho	1	New Hampshire	4	Wyoming	1
Illinois	11	New Jersey	4	Distr. of Columbia.	1
Indiana	11	New York	24	Canada.....	3
Iowa	4	North Dakota	1	England	4
Kansas	2	Ohio.....	8	France.....	1
Kentucky	1	Pennsylvania	16	Switzerland	1
Louisiana	3	Rhode Island.....	1	Germany	2
Maine	2	South Carolina	1		—
Maryland.....	2	South Dakota.....	2	Total	203
Massachusetts	20	Tennessee	4		

36 States, 4 European Countries, Canada, and the District of Columbia.

CONSTITUTION

OF THE

Society for the Promotion of Engineering Education.

1. **NAME.**—This organization shall be called the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION.

2. **MEMBERS.**—Members of this Society shall be those who occupy, or have occupied, responsible positions in the work of engineering instruction, together with such other persons as may be recommended by the Council.

The name of each candidate for membership shall be proposed in writing to the Council by two members to whom he is personally known. Such names, if approved by the Council, shall be voted on by the Society at the annual meetings.

3. **OFFICERS.**—There shall be a President, Two Vice-Presidents, a Secretary and a Treasurer, each to hold office for one year. They shall be chosen by vote of the members at the annual meeting.

4. **COUNCIL.**—The Council of this Society shall consist of twenty-one elective members, one third of whom shall retire annually. The officers and the past Presidents of the Society shall be members of the Council, *ex-officio*.

Any member of this Society shall be eligible to election to the Council, provided that not more than one elective member shall be from any one college.

Members of the Council shall be elected by ballot by the Society at its annual meeting.

The Council shall constitute a general executive body of the Society, pass on proposals for membership, attend to all business of the Society, receive and report on propositions for amendments to the constitution, and shall have power to fill temporary vacancies in the offices.

5. FEES AND DUES.—The admission fee shall be three dollars and the annual dues three dollars, payable at the time of the annual meeting. Those in arrears more than one year shall not be entitled to vote, nor to receive copies of the proceedings, and such members shall be notified thereof by the Secretary one month previous to the annual meeting. Any member who shall be in arrears more than two years and shall have been duly notified by the Secretary, shall be thereby dropped from the roll, excepting such arrearage shall be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears.

6. MEETINGS.—There shall be a regular meeting occurring at the time and place of the meeting of the American Association for the Advancement of Science, or of some one of the National Engineering Societies, or otherwise as the Council may determine.

7. PUBLICATIONS.—The proceedings of the Society, and such papers or abstracts as may be approved by the Council, shall be published as soon as possible after each annual meeting.

8. AMENDMENTS.—This Constitution may be amended by a two-thirds vote at any regular meeting, after action thereon by the Council.

RULES GOVERNING THE COUNCIL.

First. The officers of the Society shall constitute a committee to arrange the time and place of the annual meeting, and also to prepare a program for the same.

Second. The reading of papers shall be limited to fifteen minutes each, and abstracts of the same of about 300 words or less shall be printed when practicable and distributed in advance to the members.

Third. The time occupied by each person in the discussion of any paper shall not exceed five minutes.

PROCEEDINGS.

THURSDAY, AUGUST 20, 1896.

MORNING SESSION, 9:30 O'CLOCK.

The fourth annual meeting of the SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION was held in the Library Building, Buffalo, N. Y., in connection with the American Association for the Advancement of Science, most of whose meetings were held during the week following.

The meeting was called to order by the President, Mansfield Merriman. The reading of the reports of the Treasurer and the Secretary was postponed until the evening session.

The admission of new members was taken up and the following, who were approved by the Council, were elected : William R. Appleby, Bion J. Arnold, Charles Burgess, Alton C. Burnham, Regis Chauvenet, Peter Christianson, Frank H. Constant, James H. Gill, William B. Hampson, H. Wade Hibbard, Edgar Kidwell, William H. Kirchner, Charles S. Magowan, Fred Morley, William T. Sedgwick, James H. Smart, Frederick W. Sperr, Frank W. Springer, Robert J. Trammel, Jr., Francis A. Walker, George C. Whipple, James R. Willett.

It was voted that Section 3 of the Constitution be amended by the substitution of the words "Colleges" for "Schools," and "College" for "School," this amendment receiving a two-thirds vote after action thereon by the Council.

It was voted that a committee of five be appointed by the chair to bring in nominations for members of the Council on Friday morning, and for officers of the Society on Saturday evening. The President, later in the morning, appointed as such committee, C. L. Crandall, Thomas Gray, C. W. Hall, J. M. Porter, H. W. Tyler.

An invitation was received from the Engineers' Society of Western New York for an excursion on the lake on the afternoon of Thursday, which was accepted by the members. Mr. George E. Mann, President of the Engineers' Society, was introduced by President Merriman and made a brief address of welcome. The rooms occupied for meetings, and the excursions on the lake and to Niagara Falls were enjoyed through the courtesy and generosity of the Engineers' Society of Western New York.

The literary exercises of the morning opened with the reading of the Annual Address by the President, Mansfield Merriman, upon the subject "Past and Present Tendencies in Engineering Education."

Professor J. Galbraith, of the Committee on Uniformity of Symbols, presented as a report of progress, an informal statement of the work done by that committee, and after a brief discussion, it was voted that the report of progress be accepted, the committee continued, and requested to report in print not later than

one month before the next meeting. The paper by Thomas Gray on "Agreement on Definition of Engineering Terms," was read by the author and discussed by Professors Galbraith, Ordway, Fuerstes and Gray.

Professor F. P. Spalding then read a paper on "The Seminar Method as Applied to Engineering Subjects." This was very fully discussed by Professors Bull, Allen, Hatt, Randolph, Constant, Goss and Shepardson, who were present, and also by letters from Professors Wood and Turneaure. Then followed the reading by Professor F. O. Marvin of his paper on "An Experiment in the Conduct of Field Practice," which received a full discussion at the hands of Professors Fuerstes, Wadsworth, Allen and Hatt.

The meeting then adjourned to the Evening Session.

Many members improved the opportunity offered by the excursion on the lake in the afternoon.

EVENING SESSION, 7:30 O'CLOCK.

The reports of the Secretary and the Treasurer were read and accepted, and Professors Galbraith, Bull and Jacoby were appointed an auditing committee to examine the accounts of the Treasurer. Then followed the reading of the paper on "A Quarter Century of Progress in Engineering Education," by Professor Robert Fletcher, and the discussion by Professor Randolph. The next paper on "The Method of Teaching Perspective to Engineering Students" was read by the author, Professor H. S. Jacoby, and discussed by Professors Kingsbury, Hatt and Jacoby. The paper by Professor T. M. Drown on "The Study of Modern Languages in Engineering Courses" was read by Pro-

fessor H. W. Tyler, and fully discussed by Professors Wood (by letter), Bull, Fuertes, Tyler and Mees.

The paper of Professor C. H. Peabody on "A Course of Study in Naval Architecture" was read by the Secretary, and was followed by a presentation by Professor M. E. Wadsworth, of his paper on "The Elective System in Engineering Colleges" which provoked very active discussion in which Professors Galbraith, Jacoby, Bull, Magruder, Goss, Kingsbury, Bissell, and Hatt took part.

The meeting then adjourned to Friday morning.

FRIDAY, AUGUST 21, 1896.

MORNING SESSION, 9:30 A. M.

The first business in order was the election of members, and the following, whose names had been approved by the Council were duly elected : Gardner C. Anthony, Joseph N. Bradford, Frank T. Daniels, Hubert B. Mathews, Thomas R. Rosebrugh, George H. White.

The report of the Nominating Committee presented the names of the following members in nomination for the Council: A. Beardsley, R. Fletcher, J. Galbraith, W. Kent, T. C. Mendenhall, W. H. Schuerman, M. E. Wadsworth. A ballot was taken and resulted in their election.

It was voted to amend Section 5 of the Constitution by adding the following: "Any member who

shall be in arrears more than two years and shall have been duly notified by the Secretary shall be thereby dropped from the roll, except such arrearage be paid previous to the next ensuing annual meeting; and no such member shall be restored until he has paid his arrears." This had been acted upon by the Council and received a two-thirds vote at this meeting.

The question of meeting next year with the National Educational Association was taken up and discussed by Professors Hall, Fletcher, Tyler, Ostrander and Fuertes, and an informal vote taken as an expression of opinion; from this it appeared that a majority of those present favored continuing with the American Association for the Advancement of Science, it being understood that the place of meeting would probably be equally favorable in the two cases.

A letter from Past President De Volson Wood was read, which contained a number of valuable suggestions, after which the Secretary read the paper by C. C. Brown on "The Desirability of Lectures to Undergraduates on the Ethics of Engineering." The discussion which followed was carried on by Professors Wood (by letter), Wadsworth, Randolph, Fuertes and Allen. The paper on "Quantity versus Quality in Smaller Colleges" was read by the author, Professor Albert Kingsbury. The next was a paper by Mr. G. C. Whipple on "Biology for Civil Engineers," which was read by the author; Professors Fletcher and Bissell took part in discussing it.

The paper by Professor C. W. Hall, on "The Conservation of Government Energy in Promoting Engineering and Research," was immediately followed by

the Secretary's reading of the abstract of the paper by Professor W. S. Aldrich, "The Hale Engineering Experiment Station Bill," the author not being present in person or represented by the paper in full. It was thought desirable to discuss the two papers together. Professors Fuertes, Mendenhall, Wadsworth, Goss, Gray, Hamlin, Hatt, Ostrander, Magruder, Merriman and Hall joined in the animated discussion which represented wide divergence of opinion.

The meeting adjourned to Friday evening.

(No special program was arranged for Friday afternoon as it was thought desirable that members should have opportunity to use the time according to their individual tastes.)

EVENING SESSION, 7:30 P. M.

The Auditing Committee, through its chairman, Professor J. Galbraith, reported the Treasurer's accounts to be correct.

The literary exercises opened with the reading, by Professor W. H. Schuerman, of his paper, "Is not Too Much Time Given to Merely Manual Work in the Shops?" This brought forth a full discussion in which Professors Wadsworth, Randolph, Bull, Towle, Galbraith, Gray, Wilmore and Flather took part. The paper by Professor C. H. Benjamin, on "How to Divide Subjects for Original Investigation among Different Colleges," was read by the Secretary. The paper was discussed by Professors Shepardson, Bissell and Bull, and it was then voted that the suggestions of the paper for the appointment of committee be referred to the Council.

The report of the special committee on "Entrance Requirements for Engineering Colleges" was read nearly in full by the Chairman, Professor F. O. Marvin. An extended discussion followed as to the best means both of securing a satisfactory discussion from the members, and of bringing to the notice of interested educators, the valuable results reached in this report. Professors Randolph, Mendenhall, Merriman, Marvin, Magruder, Tyler, Hall and Shepardson participated in the discussion.

It was voted that the report be accepted with the thanks of the Society for the most excellent report, and that the committee be continued.

It was voted to postpone the reading of the papers by Professors Magruder and Talbot until Saturday evening.

The meeting then adjourned until Saturday evening.

SATURDAY, AUGUST 22, 1896.

The morning and afternoon were devoted to a delightful excursion to Niagara Falls and Lewiston as the guests of the Engineers' Club of Western New York. The trip to Niagara Falls was made by electric railway and was continued to Lewiston on the Gorge Railway. Visits were made to the power house of the Niagara Falls Paper Company, to the works of the Niagara Falls Paper Company, and to the plant of the Niagara Falls Hydraulic Company, where a lunch was provided by the Engineers' Club. Several other plants of interest to engineers were visited on this trip.

EVENING SESSION, 7:30 P. M.

The session opened with the paper on "Modelling as an Aid to Teaching Machine Design," which was read by the author, Professor G. W. Bissell, and discussed by Professors Flather, Goss and Bissell. Then followed the reading by Professor W. T. Magruder, of his paper on "Credit for Shop Experience in Entrance Examinations," with a discussion by Professor Bull. The paper of Professor A. N. Talbot, on "A Course of Study in Municipal and Sanitary Engineering," was read, in the absence of the author, by the Secretary. It was discussed by Professors Merriman, Allen, Hatt and Fletcher.

The Secretary then read some observations on "Civil Engineering Education," with some reference to the author's experience in Japan, which Professor J. A. L. Waddell had written in place of the formal paper on "Engineering Education in Japan," which he had hoped to find time to prepare. The discussion of this by Professors Merriman, Mendenhall and Gray closed the literary exercises of the meeting.

At the business meeting which followed, it was voted that the Committee on Entrance Requirements be requested to invite expressions of opinion on its report from colleges and preparatory schools and from educational associations, and to present a general statement of such expressions of opinion at the next annual meeting.

A letter from Professor W. S. Aldrich, containing suggestions as to certain possible enlargements of the sphere of usefulness of the Society, was referred to the Council.

The following, whose names had been approved by the Council, were elected members of the Society: John V. Hazen, George W. Patterson, Jr., Richard A. Smart.

The first two paragraphs of Section 3 of the Constitution were amended to read as follows: "The Council of this Society shall consist of twenty-one elective members, one-third of whom shall retire annually. The officers and the past Presidents of the Society shall also be members of the Council *ex-officio*.

"Any member of this Society shall be eligible to election to the Council provided that not more than one elective member shall be from any one college."

Section 4 was also amended by dropping the words "Members of the Council only shall be eligible to these offices."

A further amendment was made by substituting Section 3 for Section 4, and substituting Section 4 for Section 3.

All of these amendments were passed by a two-thirds vote of the Society after action thereon by the Council.

A letter received from Professor R. B. Owens, of the University of Nebraska, inviting the Society to hold its meeting for 1898 in Omaha, was referred to the Council.

The following vote was passed: "*Resolved*, That this Society recommends the passage of a bill providing for the adoption of the Metric System of Weights and Measures in the United States."

It was voted that the thanks of the Society be tendered to the Engineers' Society of Western New York for the many courtesies received at its hands, in-

cluding the use of their room, the excursion on the lake, and the arrangement of the excursion on Saturday, together with the entertainment provided at the Falls ; and that the thanks of the members be tendered to Mr. George E. Mann and to Mr. Edw. B. Guthrie for their personal attentions during the continuance of the meeting.

It was voted that the thanks of the Society be tendered to Mr. Eben P. Dorr, the Local Secretary, for the very satisfactory arrangements which he had made for the meeting and for the convenience of the members.

The Secretary was further instructed to convey the thanks of the Society to the Buffalo Street Railway Company, the Buffalo and Niagara Falls Railway Company, the Gorge Railway Company, for transportation furnished, and to the Niagara Falls Hydraulic Company for their efficient efforts in our behalf at Niagara Falls.

The Nominating Committee then reported a list of nominees for the various offices as follows :

President : Henry T. Eddy, University of Minnesota.

Vice-Presidents : John Galbraith, Ontario School of Practical Science ; John M. Ordway, Tulane University.

Treasurer : John J. Flather, Purdue University.

Secretary : C. Frank Allen, Massachusetts Institute of Technology.

The Society then passed a vote of thanks to the retiring President, for the valuable and impartial manner in which he had performed the duties of his office, after which the meeting adjourned.

There were present during the Session the following members: C. F. Allen, T. R. Beyer, G. W. Bissell, Storm Bull, F. H. Constant, C. L. Crandall, H. T. Eddy, J. J. Flather, Robert Fletcher, E. A. Fuertes, J. Galbraith, W. F. M. Goss, Thomas Gray, G. W. Hamlin, C. W. Hall, W. K. Hatt, H. S. Jacoby, Albert Kingsbury, W.T. Magruder, F. O. Marvin, C. L. Mees, T. C. Mendenhall, Mansfield Merriman, J. M. Ordway, J. E. Ostrander, J. M. Porter, L. S. Randolph, W. H. Schuerman, G. D. Shepardson, H. C. Solberg, F. P. Spalding, W. M. Towle, R. G. Thomas, H. W. Tyler, M. E. Wadsworth, G. C. Whipple, G. H. White, J. J. Wilmore, R. S. Woodward.

C. FRANK ALLEN, *Secretary.*

REPORT OF THE SECRETARY.

Your Secretary is pleased to report that the Society maintains the condition of prosperity which has characterized it from the beginning. It is not only steadily growing in numbers but also improving in the interest displayed, and in the quality of the papers presented at its meetings, as well as in the earnestness and thoughtful discrimination shown in the discussions. It has been possible to present the discussions of the last meeting in full in Volume III. of the PROCEEDINGS. This volume contains in papers, discussions and reports of the meetings, 395 pages as compared with 282 pages for the year previous. The number of new members elected last year was 34. There have been presented at this meeting for election to membership 22 applications, and without doubt, there will be several more on Friday and Saturday.* We shall enter upon the new year with a membership of more than 200 probably. This membership includes the presidents

* The total number elected was 31.

or directors of a considerable number of the well established technical colleges of this country, a circumstance which serves as a gratifying recognition of the fact that this Society's usefulness extends as fully to the colleges themselves as to the members of the teaching force by which the colleges are most actively represented.

The 188 members whose names appear in Volume III., represent 37 States, the District of Columbia, Canada and 5 European countries.

It is with great sorrow that the announcement is made of the death of two of our members.

Francis R. Fava, Jr., of Columbian University, of Washington, who died March 28th, had attended our last two meetings, and his activity in discussions and in the conduct of business, as well as his personal characteristics, serve to make his loss something real to those who knew him.

James H. Stanwood, of the Massachusetts Institute of Technology, who died May 24th, was present with us at the Brooklyn meeting, and personal intimacy with him gave assurance of an interest and enthusiasm on his part not inferior to that of many to whom opportunity was given for greater prominence in our Society. In both cases there is left to me a sense of personal bereavement.

Last year the address of the President brought to the attention of the members in a very forcible and, it is believed, convincing way the importance of the profession of Engineering Teaching as distinct from the profession of Engineering. The engineering colleges, in all probability, can gain more from closer contact with the preparatory schools than in any other single way. The value of the work of our Committee on Entrance Requirements as an agent in this direction, can hardly be overestimated. It is the opinion of your Secretary that this Society should strive in various ways to come into closer touch with the preparatory schools, and it is believed that great advantage would result if future meetings, or at least part of them, were held in connection with some Society whose character is distinctly educational rather than purely scientific.

The National Educational Association has a membership reaching to all parts of the country, and holds annual meetings in different cities. As the result of special inquiries, it is known that arrangements can be made by us with this Association that would be mutually satisfactory. This Association affords special facilities in the matter of transportation, as it is powerful enough to secure for its members a rate of a single fare for the round trip. Our Society is urged to consider carefully the advisability of meeting with the National Educational Association in 1897. It should be distinctly understood that our relations with the American Association for the Advancement of Science have been of the pleasantest character, and that the reason for the change, if made, would be that a Society for the Promotion of Engineering Education would derive exceptional benefit from close association with a body whose aim is distinctly and purely educational.

Respectfully submitted,

C. FRANK ALLEN, *Secretary.*

TREASURER'S REPORT.

The Treasurer of this Society would respectfully report as follows :

The total receipts during the year 1895-1896, from various sources, as given in the itemized statement below, have been \$546.07, of which \$95.07 was the balance in treasury at the beginning of the year, leaving \$451.00 as amount received from dues, initiation fees and sales of PROCEEDINGS.

The total expenditures have been \$678.83, of which about \$20.00 will be paid back to the Society (these are authors' reprints of papers read at Springfield meeting), but to offset this sum there are yet one or two small bills to be paid, the amount of which could not be obtained at the present date. This leaves a deficit of \$132.76.

There are several ways in which this deficiency may be accounted for; among these is the fact that during the past

year only \$96.00 was paid in initiation fees, whereas last year, 1894-1895, \$244.00 was received from the same source.

In the sale of the Transactions of the Society also there was a large discrepancy; during the previous year there was received \$109.00 for back numbers and extra copies of the PROCEEDINGS; against which only \$17.00 has been received during the past year.

It is evident that the action of the Society in increasing the dues from \$2.00 to \$3.00 per annum, which goes into effect the coming year, was a wise provision, but even this increase will not yield a sufficient income to carry on the work of the Society and pay off the indebtedness of the past year.

The receipts from initiation fees for the coming year will probably reach \$100.00, and the dues about \$600.00; but there will be required at least \$150.00 additional, and this sum must be obtained from the sale of the Society's PROCEEDINGS.

It is urgently advised that each member who has not already a complete set of these valuable Transactions should order the omitted volumes at an early date.

The Treasurer would also suggest that each member use his influence toward placing a set of these PROCEEDINGS in the library of the respective colleges represented.

(It might be stated that the volumes may be obtained from the Secretary, at a cost of \$2.50 per copy. There are now 3 volumes.)

A condensed statement of receipts and disbursements for the year is appended herewith.

Respectfully submitted,

JOHN J. FLATHER, *Treasurer.*

Statement of the Treasurer of the Society for the Promotion of Engineering Education for the year 1895-1896:

RECEIPTS.

Balance on hand September 1, 1895	\$95.07
Initiation fees	96.00
Past dues	12.00
Advance dues	2.00

Current dues	\$324.00
Publications	17.00
Total	\$546.07
Deficit, August 20, 1896	132.76
	\$678.83

DISBURSEMENTS.

Postage	\$68.60
Stationery and typewriting	12.80
Stenographer (Springfield meeting)	75.00
Printing of circulars, etc.	88.60
Printing and binding PROCEEDINGS	408.00
Printing authors' reprint of papers	21.45
Telegrams, express, etc.	10.88
Exchange on checks	8.50
Total	\$678.83

JOHN J. FLATHER, *Treasurer.*

REPORT OF THE AUDITING COMMITTEE.

The Auditing Committee beg to report that they have examined the statement of the Treasurer, compared it with the vouchers and find it correct.

J. GALBRAITH, *Chairman.*

AUGUST 21, 1896.

ADDRESS BY THE PRESIDENT.

PROFESSOR MANSFIELD MERRIMAN.

Past and Present Tendencies in Engineering Education.

The present status of engineering education in the United States is the result of a rapid evolution which has occurred in consequence of changes of opinion as to the aims and methods of education in general. These changes of opinion, whether on the part of the public or on the part of educators, together with the resulting practice, may be called tendencies. All progress that has occurred is due to the pressure of such views or tendencies ; hence a brief retrospect of the past and contemplation of the present may be of assistance in helping us to decide upon the most advantageous plans for the future.

Thirty years ago public opinion looked with distrust upon technical education. Its scientific basis and utilitarian aims were regarded as on a far lower plane than the well-tried methods of that venerable classical education whose purpose was to discipline and polish the mind. What wonderful changes of opinion have resulted; how the engineering education has increased and flourished ; how it has influenced the old methods, and how it has gained a high place in public estimation, are well known to all. The formation of this Society in 1893, its remarkable growth, and the profitable discussions contained in the three volumes of its transactions, show clearly that technical education constitutes one of the important mental and material lines of progress of the nineteenth century.

Engineering courses of study a quarter of a century ago were scientific rather than technical. It was recognized that the principles and facts of science were likely to be useful in the everyday work of life and particularly in the design and construction of machinery and structures. Hence mathematics was taught more thoroughly and with greater regard to practical applications, chemistry and physics were exemplified by laboratory work, drawing was introduced, and surveying was taught by actual field practice. Although engineering practice was rarely discussed in those early schools, and although questions of economic construction were but seldom brought to the attention of students, yet the scientific spirit that prevailed was most praiseworthy and its influence has been far reaching.

This scientific education notably differed from the old classical education in two important respects : first, the principles of science were regarded as principles of truth whose study was ennobling because it attempted to solve the mystery of the universe ; and second, the laws of the forces of nature were recognized as important to be understood in order to advance the prosperity and happiness of man. The former point of view led to the introduction of experimental work, it being recognized that the truth of nature's laws could be verified by experience alone ; the latter point of view led to the application of these laws in industrial and technical experimentation. Gradually the latter tendency became far stronger than the former, and thus the scientific school developed into the engineering college.

The very great value of laboratory experiments, and

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of all the so-called practical work of the engineering school to-day, is granted by all. Principles and laws which otherwise may be but indistinct mental propositions are by experimentation rendered realities of nature. The student thus discovers and sees the laws of mechanics, and is inspired with the true scientific spirit of investigation. It should not, however, be forgotten that if such practical work be carried beyond the extent necessary to illustrate principles it may become a source of danger. The student of average ability may pass a pleasant hour in using apparatus to perform experiments which have been carefully laid out for him, and yet gain therefrom little mental advantage. Especially is this true when the work assumes the form of manual training, which, however useful in itself, is properly considered by many as of too little value to occupy a place in the curriculum of an engineering college.

The tendency towards the multiplication of engineering courses of study has been a strong one, especially on the part of the public. This has resulted in a specialization that, as a rule, has not been of the highest advantage to students. In some institutions this has gone so far that the student of civil engineering learns nothing of boilers and machines, while the student of mechanical engineering learns nothing of surveying or bridges. The graduate is thus too often apt to lack that broad foundation upon which alone he can hope to build a successful career.

The development of the scientific school into the engineering college has been characterized throughout by one element of the happiest nature, that of hard

work and thoroughness of study. The numerous topics to be covered in a limited time, their close interrelation and the utilitarian point of view, have required many hours per week and earnest work by each student in preparation for each exercise. The discipline of hard and thorough work is one whose influence can be scarcely overestimated as a training for the duties of life, and in every university it is found that the activity and earnestness of the engineering students is a source of constant stimulus to those of other departments. Thus scientific and engineering education has tended to elevate the standard and improve the methods of all educational work.

The length of the course of study in engineering colleges has generally been four years, and whatever tendencies have existed towards a five-years' course have now for the most part disappeared. With higher requirements for admission, particularly in English and in modern languages, a reduction of the length of the course to three years may possibly be ventured in the future, particularly if the long summer vacation be utilized for some of the practical work, as, indeed, is now the case in several institutions.

There has been and now is a strong tendency toward a reduction in the length of the college year. While formerly forty or fortytwo weeks were regarded as essential, the process has gone on until now some colleges have but thirty or thirtytwo weeks, a reduction of nearly twentyfive per cent. having been effected in twentyfive years. Undoubtedly the long vacation is utilized to great advantage by the majority of students in actual work, yet the fact remains that it is

not good business economy to allow the buildings and plant of a college to lie idle for so large a part of the year. It is perhaps possible that in the future the summer schools may be so developed that the work will be practically continuous throughout the year, thus giving to students the option of completing the course either in three or four years.

The report of the committee on requirements for admission, which will be presented later in the session, sets forth many facts which show the tendencies now existing. Almost without exception a higher standard is demanded, both that students may enter with better mental training and that more time may be available in the course for technical subjects. While the general line of advance is toward an increase in mathematics and in modern languages, there is also found, particularly in the Central States, a demand for broader training in science. It has already been pointed out that our early engineering schools were strong in scientific training, and that the tendency has been to replace this by industrial applications. If the requirements for admission can be extended to include the elements of chemistry and physics, with some botany or zoölogy, the engineering student will enter with broader views, a keener power of observation, and a scientific spirit that will greatly increase his chances for success in technical studies.

The general increase in requirements for admission tends to raise the average age of the student. It is now usually the case, owing to the greater length of time needed in preparatory work, that the average age of the classical student is one year higher than that of

the engineering student; or the former has had one more year of training than the latter. One more year of training means much as an element for success; one more year in age means an increase in judgment which is of the highest importance for a proper appreciation of the work of the course. The older men in a class usually do the best, if not the most brilliant work, and after graduation their progress is the most satisfactory. It thus appears that all tendencies that raise the age of entrance are most important ones and deserve hearty encouragement.

Having now considered some of the general elements and tendencies in engineering education it will be well to take up the program of studies, especially in regard to those subjects that are common to all technical courses. The three volumes of the Transactions of this Society contain many carefully prepared papers and interesting discussions which enter into questions of detail concerning nearly all topics in the curriculum. Here, however, can only be noted briefly the main lines of development and the indications for future progress.

Mathematics is undoubtedly the most important subject in all courses of engineering study, and it has been demanded for years that it be taught with great thoroughness. This demand has been met more completely in the independent engineering colleges than in the engineering courses of the universities. Much, however, remains to be done in this direction, and probably it can not be satisfactorily accomplished until a change in method has been effected. The fundamental element in the change of method must be,

it seems to me, in a partial abolition of the formal logic of the text-books and an introduction of historical and utilitarian ideas. Mathematics is a tool to be studied for its uses, rather than for its logic or for the discipline that it can give; hence let its applications be indicated frequently and not be systematically kept out of view. If the student gains the impression that his mathematical exercises are merely intended to train the mind, his interest and his progress will usually be slow. If, however, he learns what mathematics has done in the past, how it joins with mechanics to explain the motions of the distant planets as well as to advance the material prosperity of man, there arises an interest and a zeal that helps him to overcome all difficulties.

The great advantage of numerical exercises in all branches of pure and applied mathematics, and the deplorable lack of good preparation in arithmetic, have been expressed by many educators. In numerical computations the average engineering student is weak in spite of the numerous exercises in his practical work. To remedy this defect better instructions in arithmetic is demanded in the common and high schools, while in engineering colleges the teachers of mathematics should constantly introduce numerical work and insist that it be done with a precision corresponding with the accuracy of the data.

Next to importance in mathematics comes mechanics, the science that teaches the laws of force and motion. In most institutions the rational is separated from the applied mechanics and often taught by the mathematical department. Probably less improvement has re-

sulted in the teaching of rational mechanics during the past quarter of a century than in any other subject. That mechanics is an experimental science whose laws are founded on observation and experience is often forgotten, and the formal logic of the text-books tends to give students the impression that it is a subsidiary branch of mathematics. The most interesting history of the development of the science is rarely brought to the attention of classes, and altogether it appears that the present methods and results are capable of great improvement.

It should not be overlooked, however, that in recent years the so-called absolute system of units has been introduced into mechanics, and is now generally taught in connection with physics. Here the pound or the kilogram is the unit of mass, while the unit of force is the poundal or the dyne. Although this system possesses nothing that is truly absolute, it has certain theoretical advantages that have commended its use, notwithstanding that no practical way of measuring poundals has been devised except by the action of the force of gravity on the pound. Engineers have continued to employ the pound weight as the unit of force, and the calculations of the physicist must be translated into the units of the engineer before they can be understood. The student of rational mechanics thus has the difficulty at the very outset of two systems of units, and great care should be taken that each be thoroughly understood and the relations between them be clearly appreciated by application to many numerical problems. In view of these and other difficulties, and of the novelty of the subject in general, it appears that

some engineering colleges do not give to rational mechanics as much time as its importance demands.

Physics, in some colleges, is taught by a course of five or six exercises per week, extending over a year, while in others the elements are required for admission and the regular course is correspondingly abridged. The marvelous development of electrical theory and practice has naturally tended to make this the most important topic in the course, sometimes indeed, to a material abridgment of mechanics, acoustics, thermodynamics and optics. Considering how great is the importance of each branch of physics and the advances that are made every year in the new directions, it may also be concluded that more time can be profitably given both to theory and experimental work. Physics is a fundamental subject whose principles and results are of constant application in every walk of life, and a student who thoroughly covers a well arranged course has gained a mental discipline and a scientific habit of mind that will be of greater value than the technical details of a purely engineering specialty.

Undoubtedly the most powerful tendency in engineering education has been in the direction of the development of those special technical subjects which may be grouped under the name of Construction and Design. In civil engineering this has led to plans for railroad, water supply and bridge constructions; in mechanical engineering to engine and machine design, in mining engineering to projects for mine plants, and in electrical engineering to the design of dynamos and motors. These courses have been demanded by the public and by the students themselves, and have been

often elaborated to an extent beyond the best judgment of teachers of engineering. To the extension of such courses there is no limit, but it is a question whether the process has not already gone too far. For instance, it would not be difficult to arrange a course of twenty or thirty exercises on water pipes in which should be discussed all the methods of manufacture and processes of laying cast-iron, wrought-iron lap-welded, steel-riveted and wooden mains, together with a comparison of their relative economies under different conditions in different parts of the country. These lectures, however, would plainly be of such a technical nature that the advantage to the student would be slight; they would give valuable information, but little training.

In all courses in construction and design the practical limit seems to be reached when the exercises are of such a nature as to give mere information and little scientific training. The aim of all education, and of engineering education in particular, should be to render the student conscious of his mental power and sure of applying it with scientific accuracy so as to secure economy of construction. Fundamental principles are hence more important than the details of a trade, and all exercises in design should be arranged so that the student may think for himself rather than blindly copy the best practice of the best engineers.

The subject of applied mechanics, which occupies an intermediate place between rational mechanics and the work in design, has been so differentiated that the mechanics of materials is now almost the only topic common to all engineering courses. The strongest line

of development has here been in the introduction of testing machines and in the making of commercial tests. This work is of high value, although it may be doubted if the use of one or two large testing machines is as advantageous as that of many smaller ones which are designed especially to illustrate principles. The student of the present day enjoys, however, advantages that were unknown a quarter of a century ago, and the marked progress in applied mechanics from both the scientific and technical point of view is a source of congratulation.

English and modern languages are generally called culture subjects, and it is well known that of all the topics in the engineering course these are the ones in which students have the least interest. The great importance to an engineer of being able to clearly and correctly write his own language can scarcely be overestimated. Further it may be said that no engineer can hope to attain eminence unless he can read German and French literature. These opinions have long been held, and furthermore it has been recognized that engineering students and graduates are often lacking in that general culture which the world demands as one of the conditions of success. Great improvements have been made in the methods of teaching English and modern languages, and probably still greater ones are yet to result. In the ideal engineering colleges of the future, perhaps these subjects will be required for admission, as is now done by at least one institution, but at present they must generally be taught. The main line of improvement to secure better results will be, it seems to me, in partially

abandoning the idea of culture and placing the instruction upon a more utilitarian basis. If English be regarded as a means to an end instead of linguistic drill, if the aim of teaching French and German be to read fluently the language of to-day instead of laboriously to decipher the meaning of the poets of centuries ago, true zeal on the part of students will arise and a truer culture will result.

At the close of the college course the student presents a thesis showing his ability to apply the principles and rules of engineering in the investigation or design of a special problem. The tendency has been strong to abandon subjects which involve mere descriptions or compilation, and to insist upon those that will require the student to exercise his own powers. Thus the value of the work to the student has been greatly increased, and the theses of each class are a source of stimulus to the following ones. Although the view held by some that theses should be monographs setting forth important conclusions of original investigations, is one that can not in general be realized, it is a gratification to note that each year a few theses are produced which are sufficiently valuable to warrant immediate publication.

The formation of engineering clubs among students for the discussion of the details of professional work is one of the most important tendencies of recent years. No exercise is so valuable to a student as one entirely originated and performed by himself, and the preparation of a paper which is to be presented to and criticized by his fellows ranks highest of all among such exercises. Recently there has been forced upon my

notice a remarkable activity in the three engineering clubs of a certain engineering college, more than fifty papers having been read and discussed during the year by a total of about three hundred and fifty students, besides a number of others read before the mathematical club. In meetings of this kind the scientific and economic questions under discussion in the engineering journals receive a detailed attention which the professor in the class room often finds it impossible to give, while the advantage to students in expressing themselves in debate is very great.

Occasional lectures to classes by practicing engineers have been introduced in many institutions during the past decade, and with uniformly good results. In engineering education there is no conflict between theory and practice, and every professor cordially welcomes distinguished engineers to explain their great structures and achievements to his classes. It is an inspiration to students to see and hear those men who have so successfully applied sound science to economic construction, and whose influence has been uniformly to elevate the standard of the profession.

After four years of work the engineering student receives his degree and is ready to commence the actual work of life. What the letters are that designate the degree is a matter of small importance. Moreover, if we examine the lists of alumni who graduated ten or fifteen years ago, the conviction arises that their particular course of engineering study has not been an absolute factor in determining their actual line of engineering work. It is found that graduates in civil engineering are engaged in mining, in machinery and

in electricity, and that graduates in other courses are employed upon work in which they received no especial technical instruction. Thus it appears also that the particular course of engineering study is not so important a matter as students and the public generally suppose. In fact, a young man thoroughly grounded in fundamental principles and well trained how to apply them has almost an equal chance for success in all branches of engineering practice.

Looking now over the field of tendency thus briefly outlined, it is seen that there has been ever present a powerful impulse towards specialization, to which, indeed, nearly all others have been subordinated. This has demanded a higher standard of admission, great thoroughness in all fundamental subjects, and a rigid adherence to scientific methods. Engineering education has had an active and healthy growth; it now enjoys the respect and confidence of the public, and its future is sure to be more influential than its past. It is not specialization that has caused its success, but rather the methods which specialization has demanded. Those methods have resulted in imparting to students zeal and fidelity, a love of hard work, a veneration for the truths of science, and a consciousness of being able to attack and overcome difficulties ; these elements of character are, indeed, the foundations of success in life.

Looking now forward into the future, it is seen that in our efforts for the promotion of engineering education a wide field for work still lies open. The student should enter the engineering college with a broader training and a more mature judgment. The present

methods of instruction are to be rendered more thorough and more scientific. In particular, the fundamental subjects of mathematics, physics and mechanics are to be given a wider scope, while the languages and the humanities are to be so taught as to furnish that broad, general culture needed by every educated man. In general let it be kept in mind that education is more important than engineering, for the number of men who can follow the active practice of the profession will always be limited. Hence let it be the object of engineering education to influence the world in those elements of character that the true engineer possesses, so that every graduate may enter upon the duties of life with a spirit of zeal and integrity, with a firm reliance upon scientific laws and methods, and with a courage to do his work so as best to conduce to the highest welfare of his country and of mankind.

A QUARTER CENTURY OF PROGRESS IN ENGINEERING EDUCATION.

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THE HISTORICAL BACKGROUND OF THE STATUS OF 1870.

The "Committee of Civil Engineers" which edited the Reports of Smeaton in 1812 made this observation: "Before or about the year 1760 a new æra in all the arts and sciences, learned and polite, commenced in this country (Great Britain). Everything which contributes to the comfort, the beauty and the prosperity of a country, moved forward in improvement so rapidly and so obviously as to mark that period with particular distinction." After brief reference to the enormous development of manufactures, internal navigation, harbor works, military and naval establishments, etc., they add: "This general situation and condition of things gave rise to a new profession and order of men called CIVIL ENGINEERS."

The "æra" was that of Brindley, the early canal builder; Smeaton, who first bore the title of the new order; Metcalfe, the blind road builder; Rennie and Telford, whose various works covered the kingdom; and Watt and Stephenson, whose mechanical triumphs gave to mankind all the potentialities of the steam engine and locomotive.

And yet it was a tardy awakening. Although Myddleton, a century and a half before, had brought the New River water into London, Drake had given an aqueduct to Plymouth in 1594, and Vermuyden from Holland had executed great levees, embankments and drainage works, Smiles says:—" * * * we depended for our engineering, even more than for our pictures and our music, upon foreigners. At a time when Holland had completed its magnificent system of water communications, and when France, Germany and even Russia had opened up important lines of inland communication, England had not cut a single canal, while our roads were about the worst in Europe."

But, while the profession was rising in England to dignity and honor, there was no organized system of technical education. It was the period of self-taught men. Only in rare cases did early advantages include the university. These men came slowly to professional maturity; were developed from the conditions and needs of the times; both made the profession and were made by it. Apprenticeship in the engineer's office was both the school and the road to advancement. Methods were empirical; knowledge of principles imperfect; economic conditions and necessities too much ignored; and the great works, many of them monumental, are not examples for modern imitation. Nevertheless the system has borne magnificent fruit in the vast and enduring—but usually too costly—works, which have been the chief means of establishing and confirming British domination in every quarter of the globe.

* *Lives of the Engineers.* Vol. 1, Introduction.

What may be termed the first regular school of engineering in England began as late as 1840, in University College, London. The same year saw the chair of civil engineering founded by Queen Victoria in the University of Glasgow, where Rankine did so much for engineering education. The well-known Thomson Engineering College at Roorkee, India, was founded in 1847, and in 1892 there were four engineering colleges in that country. Five years ago official statistics named 41 engineering schools in the entire British empire, nearly half in the colonies; but the greater part of these were properly schools for artisans. In 1876 Capt. Douglas Galton testified that, even then, the successive stages for a civil engineer were: A liberal education at some school or college; regular or apprenticed pupil to a leading engineer; assistant to an engineer; and, finally, independent practice. Only three years ago a noted English engineer, before the world's greatest engineering society,* deplored the continued past neglect of abstract science and theoretical training by the great body of English engineers.

Turning to France we find early recognition of the value of organization in the conduct of public works. The Corps des Ponts et Chaussées was established by law in 1716. The importance of systematic technical instruction was so clearly perceived by Perronet that he is said to have made a beginning for the École des Ponts et Chaussées in 1747, and labored for it until its official recognition by an order of Turgot in 1775. (The magnificent stone bridges and other public works

* Address of Prof. Anderson, Engineering, LV., 682.

of this distinguished engineer doubtless served as models for the next generation in England.—Bridge of Neuilly, 1768–1773.)

The year 1765 saw the beginning of the famous Mining Academy at Freiberg; 1794 of the École Polytechnique at Paris, by act of the National Assembly; 1815 the Polytechnic of Vienna, and 1821 of the Royal Polytechnic Institute of Berlin. These and later schools on the Continent have largely made the profession there, and have exerted a constant dominating influence upon it. The prestige of governmental control and generous support, the high rank of leading professors, not only as teachers, but as investigators, practicians and authors, have, during half a century or more, attracted many American students who, in their turn, have had a large and healthy influence upon the schools and practice in America.

American engineering practically begins with this century, and the United States Military Academy was, from the start, a nursery of civil engineers. Its first graduate in 1802, General Swift, was a distinguished military and civil engineer. During more than half a century, about two hundred of its graduates became civil engineers, some of whom achieved the highest distinction; and this not because civil engineering ever had a very large place in the curriculum, but because the rigid military discipline and thorough instruction in mathematical and physical science, well equipped its graduates for the exigencies of that period. Thence issued, in 1837, the first formal treatise on civil engineering in English. Its honored author, Professor Mahan, gives a list of works then available to the stu-

dent, an instructive glimpse of the book resources of that day.* His own text book was so well esteemed that in 1872, fifteen thousand copies had been sold ; it was reproduced in quarto form in England, was used in one of the Government schools in India, and was translated in whole or in part into several foreign languages.

The name of the Rensselaer Polytechnic Institute of Troy is synonymous with engineering education in America. Founded in 1825, nurtured by the wisdom of Amos Eaton, sending out the first *graduate* civil engineers of the English-speaking world in 1835, just at the opening of the railway era, it has, from its early start, ever maintained the highest standard of effective training in its course for civil engineers. Its graduates have been in the fore-front of the profession for fifty years.

* This list was : Sganzin's Programme of Civil Constructions at the Polytechnic, Paris ; Edinburgh Encyclopedia, articles on bridges, canals and carpentry ; Tredgold's Carpentry and Tredgold on Cast Iron ; Transactions of the Society of Civil Engineers ; De Pambour on the Locomotive ; Wood on Railroads ; Storror on Conveyance of Water ; De Gerstner, Chemins Orniére ; Treussart on Mortars ; all the works of Navier (then an author since 1817).

We must note that Mr. Storror's work (1835) was probably the first systematic treatise on hydraulics in English. Its author (still living) graduated from Harvard, studied in the French schools, and not long afterwards built the works of the Essex Company, at Lawrence.

Prof. D. H. Mahan was himself a graduate of the United States Military Academy, a special student in France, for 37 years the head of the department of military and civil engineering at the Academy, and the author of no less than six works on military and civil engineering, all of which were widely used as standard for half a century.

We may note also that Davies, Church and Bartlett, distinguished graduates and professors at the Military Academy, by their admirable treaties on mathematics, physics and astronomy, exerted a wide influence in promoting the best technical education throughout the United States.

These were some of the results of the administration of Col. Sylvanus Thayer, the reorganizer and "father" of the Military Academy, from 1817 to 1833.

The Franklin Institute of Philadelphia, through its drawing school and lecture courses, also did a useful work after 1826 in the elementary instruction of engineers as well as of artisans.

As our thought is upon early history, other well-known schools need no mention here.

But, apart from the schools, as in England, we survey a goodly line of eminent men who owed little or nothing to such aid ; men of native ability, whose training was on the works and in the office. However, the results in America were better than in England. Lack of resources forbade costly experiments. The judicious adaptation of small means to the greatest possible outcome established the true principle of engineering practice. Before 1840, American engineers had already achieved a world-wide fame by the novelty and magnitude of their works. The builders of the early canals and railroads soon departed from English precedents, and the famous constructors of timber bridges and promoters of steam navigation set examples for the world, even from the first decade of the century.

In Stuart's "Lives" of twenty well-known American engineers, born between 1731 and 1827, one quarter were school-trained—three at West Point, one at Yale, and the last, Roebling, at the Royal Polytechnic, Berlin.

This summary of antecedent conditions may be concluded by briefly viewing, in the United States,

THE SITUATION BETWEEN 1860 AND 1870.

In 1866 there were six engineering schools of established reputation which had graduated during the

previous thirty-one years about 300 students. During the next five years the number increased from six to twenty-one, and the total of engineering graduates from 300 to about 850.

The schools had very inadequate resources; engineering laboratories for general instruction were practically unknown,—although here and there a professor was improvising experiments on a small scale; (tests of materials by practising engineers not here considered;) text-books were few and many derived from abroad; instruction was probably more largely by recitation from the book, with great emphasis on purely mathematical exposition, according to the methods of Navier, D'Aubisson, Morin, Bresse, Moseley, Rankine, etc.; the subjects taught were much the same by name as those taught to-day, but not so many, not so practically developed, and without aids now deemed essential; they were, however, fundamental, and the capable student got a firm grasp of principles.*

An important feature of the situation at that time was the general sentiment of the profession towards the schools. This appeared emphatically in the memorable joint discussion of 1876 before the Engineering Societies—provoked by the notable paper of Mr. Holley on "*The Inadequate Union of Engineering Science and Art.*" It was claimed that engineering instruction was almost solely devoted to abstract principles; that it was largely misdirected because sepa-

* See Rickett's History of the Rensselaer Polytechnic Institute, p. 99, for programme of studies and text-books in 1854. This names 29 text-books,—eight of foreign authorship,—and alludes to 129 works of reference in English, French and German.

rated from the objects, phenomena and conditions of practice; it was, therefore, ineffective and usually contemned by the practicians; the spheres of the investigators, school men and men of engineering affairs were too wide apart, and their labors not correlated; the young graduate was said to be nearly useless even as a conservator; a change was demanded which would result in a better adaptation of means to ends and make the graduate more immediately available.

Never before had activity in all construction been so widespread. Railroads, bridges, water works, sewerage works, and mining and metallurgical plants were demanded over the face of the continent. Hundreds were crowding or were being pressed into service with little or no proper education. Chainmen and axmen speedily became transitmen and "engineers." To such practicians the defects of the schools were more obvious than their own deficiencies. Yet the value of technical training began to be realized by some who had only crude ideas as to what it should be. Those who believed in giving first place to theoretical instruction could point to examples of noted engineers both at home and abroad. But the field was widening; new materials and forms of construction were coming into use; new experimental data were needed; hence the proper scope for an engineering course was rapidly enlarging—and there was good reason for the demand that the schools should keep in better touch with the profession.

With this necessary background, familiar, perhaps, certainly brief and imperfect, we pass to a view of

THE PAST QUARTER CENTURY OF ENGINEERING EDUCATION.

Extreme brevity is compulsory ; the leading facts and conditions may be well enough known ; suggestive outlines must suffice.

Progress appears by contrasts. A special Committee of this Society reported last year 109 institutions rated as engineering "colleges" or schools, including all grades. This is a five-fold increase since 1871 and is certainly excessive.

In 1892, the total of graduates from 52 engineering schools, recognized as such in the series of articles by *Engineering News*, was about 9,000. Of these, 5,400 from 45 schools were rated as civil engineers ; about 2,800 from 33 schools as mechanical engineers ; about 870 from 15 schools as mining engineers ; and more than 200 from 20 schools, within the previous two years only, as electrical engineers. This differentiation dates from about 1867 for mining schools, from 1870 for schools of mechanical engineering, and from 1885 for courses in electrical engineering.

Within the colleges we find notable expansion into other special courses, denominated : railroad engineering, hydraulic engineering, sanitary engineering, chemical engineering, etc., to such extent that in some quarters ten or more distinct courses are offered, for some of which the proposed outcome is specialists in as many separate branches of engineering.

Thirty years ago the few schools were in modest quarters, with scant equipment. Now the many schools have ample buildings, and some occupy struc-

tures which are magnificent, and even extravagant, in size and appointments, notably in Europe.

A quarter century ago student work in the laboratory was just initiated by an American professor and scientist for the study of chemistry and physics.* Now we are in an age of laboratories. Not only are they provided for testing all important properties of materials on the largest scale, for hydraulic tests and verifications, and for metallurgical studies, but a recent writer has said that a mere list of the subjects for which there exist well-equipped special laboratories, would astonish even the most well-informed man.† What is now deemed adequate instruction for the would-be mechanical and electrical engineer becomes impossible without at least a moderate provision of standard machines and measuring appliances. Although it is a fact that the magnificent library and museums of ancient Alexandria had auxiliary laboratories for researches in anatomy and physiology, the modern application for instruction is hardly older than the present generation.

Then European schools were regarded as models. Now some American schools have no superiors for meeting the demands of American practice. Moreover, both German and English educators have quite recently recognized the superiority of American schools in their effective use of the engineering laboratory, and have urged the adoption of similar means in their own countries.‡

* Prof. Wm. B. Rogers.

† Johns Hopkins Hospital Bulletin, No. 58, Jan., 1896.

‡ It must be remembered, however, that as early as 1878, Prof. Kennedy established the first engineering laboratory in the United Kingdom, in University College, London, whether for general use by students the writer does not know. See Engineering, LV., 728.

Then handicraft had not been recognized in our educational methods, although shop-work instruction was just gaining some attention as an innovation from abroad. Now, not only for trade schools, but in leading engineering schools, the manual training in carpentry, smith work, foundry work and machine work is carried to its full value for an engineering course—and, perhaps, more than a little beyond.

But progress measured only by quantity, and objectively, may be more apparent than real. Schools, with their appliances, are but means to an end. From the concrete and visible we must look for an invisible or spiritual result, which like energy is measured solely by the effect produced. Hindering conditions must be recognized. Doubtless there are, to-day, too many schools and too many students; doubtless standards of admission are too low, and, consequently, too many studies are forced upon immature and half-trained mental capacity, which is unable to co-ordinate the great variety of work, and derive therefrom a well-balanced and effective discipline; doubtless some are beginning too early, without the needed foundation of general culture, and then turning with undue haste into some specialty, so as to integrate the professional life between narrow limits from which it may be difficult, if not impossible, to retrieve it. Doubtless there have been cases of misdirected private munificence in the starting of new institutions, instead of strengthening the old and well-tried; doubtless one-half of the present number of schools with the same total of resources, might meet more effectively all real demands; yet each has apparently a legitimate field. There are

back steps which cannot be recovered, as well as tendencies which may be corrected.

This Society, which is now widely recognized as a power for promoting technical education, has responsibilities. Our former Secretary has truly said that "the task which it has set itself to perform is nothing less than shaping the future of technical education, not only in America, but, by example, in all the world." The body of the Profession may well call upon it to define "engineering education," to formulate and uphold a high standard, to recognize admissible limitations, and to propound not an impossible, but a practicable ideal.

This responsibility of the Society, as well as of the schools, may be viewed best in the light of some other influences and accomplished results, brought about not by argument, nor only by expounders of natural science, but by the unanswerable logic of the example and fruits of the schools of technology.

The influence of technical education upon the older and traditional learning. We need only allude to the profound changes in the courses of study of all our leading colleges and universities. Out of this quasi-revolution has come the elective system, not as a mere expedient, but as a proper enlargement of the function of the college. However, this must carry with it a corresponding development of the power of the student to make intelligent choice. The distinguished President of one of our oldest and most wisely conservative colleges has said: "It is always and everywhere the function of the college to give a liberal education, beyond which and out of which the process of specializa-

tion may go on in any direction and to any extent. The college must continually adjust itself to make proper connection with every kind of specialized work, not to do it." Quoting Virchow, who claims that "mathematics, philosophy and the natural sciences give the young minds so firm an intellectual preparation that they can easily make themselves at home in any department of learning," he adds: "With few exceptions, the greater scientists among us are taking their place in literature. They are recovering the original qualities of style—simplicity, clearness, vividness. Some of them have caught with remarkably close ear the accents of the English tongue."*

Finally, under this head, we know how many observers have called attention to the *strenuousness of endeavor* exhibited by students in the engineering schools, and the greater effectiveness of the instruction, because the practical and fruitful ends in view offer more direct and, therefore, more sufficient incentive.

Progress is evident also in the inevitable *reaction of the schools upon the profession*. In the ranks of the profession the school graduates have passed from a hopeless minority to an influential majority. With a few brilliant exceptions, the great achievements in American engineering in the past twenty-five years have been wrought by men who have owed much to a broad education, or a technical training, or both. Conspicuous failures of important undertakings, and of minor works all over the land, mark the course of

* Inaugural address of President Wm. J. Tucker, Dartmouth College, on "The Historic College."

some "practical" men who have gloried in their lack of technical education. Some of the very best treatises in the ever-widening range of special departments have come from the schools; we need not specify works on bridges, roofs and buildings, masonry construction, hydraulics, materials, sanitary works, experimental methods, etc., adjudged by critics both at home and abroad to be the best extant, and promptly adopted as standard or for reference by practising engineers. The schools have given the profession important results of special researches, especially on properties of materials, although such work is not a necessary function of the school. The graphical statics, that powerful and time-saving method of analysis and computation, is a gift from the schoolmen to the practitioners, which was too long not half appreciated. The engineering societies now put large value upon school training in their requirements for admission to membership. It is also significant that some engineers refuse to employ as responsible assistants, men who have not had a full engineering course in a good school. The best men of so-called practical training now generally concede both the value and necessity of school training, and often regret their own lack of it.

A corresponding *counteraction of the profession upon the schools* is seen in the large recruitment of the force of teachers from the ranks of practicing engineers; in the cordial coöperation of the practitioners and managers of works, by which students are given free access to every variety of plant and construction; in the present availability of the Transactions of Engineering

Societies and the current issues of the technical engineering journals; (for we must remember that there was very little of that kind published in America thirty years ago,—a few modest serials devoted to railroads, machinery and metallurgy). We may allude also to the array of manuals, field-books, special treatises and descriptive albums prepared by leading engineers, and embodying results of latest experience and research, not only for the profession at large, but often especially for the use of students.

In this connection we are forced to notice the unfavorable bearing of the excess of schools and graduates upon the relation between the schools and the profession. The superfluous graduate is in danger of becoming an unwelcome intruder—a disturber of equilibrium—treading upon the heels of his senior, often crowding aside the more experienced and more competent man and lowering the rate of compensation, especially in the middle ranks. And yet Telford, in 1830, before either England or America had seen a graduate civil engineer, complained that the profession was overstocked, and tried to dissuade young men from entering it. Also at the Philadelphia conference in 1876, older engineers declared that engineering was then overdone.

In 1892, investigation showed that out of 3,540 graduates of engineering schools, 59 per cent. were strictly in engineering pursuits, 7 per cent. were railway officials, $6\frac{6}{7}$ per cent. managers of works, 2 per cent. contractors, and $25\frac{4}{7}$ per cent. in other occupations. At the same time the membership of the American Society of Civil Engineers showed only 56 per cent. in

strictly full practice, 21 per cent. in related pursuits, and $22\frac{7}{10}$ per cent. not specified, but mostly not practicing or in some other business. However unfavorably we may interpret these figures as showing an excess of supply, and a crowding out of a rather large percentage from regular practice, they illustrate the well-known distinctive advantage of this profession that both the school training and the professional experience qualify men for a variety of other pursuits.

The true sphere and responsibility of the school to-day must be viewed in the light of its environment.

Mechanical engineering, while in some relations divided off as a distinct province, invades the field of the civil engineer at every point, both limiting the conditions of his working and yet affording amazing appliances for almost incredible achievements. (We are reminded that Smeaton, the first titled civil engineer, was a skillful mechanic, who perfected and applied the rude machinery of that time in his larger professional field.) What was a mere department in the study of natural science two decades ago, has grown into the branch of electrical engineering, in which the practice is unusually dependent upon theory and exact knowledge. The engineer of to-day brings diverse science to his aid; he coördinates the labors of the chemist and biologist, and makes the results fruitful in works for restoring the purity of water for large communities. Photography serves him both as witness and recorder and chief observer in the field. Architecture is no longer wholly apart; the monstrous building calls for the engineer to make a sure foundation, as well as a safe design for the framework. These and other aspects

and results show how multifarious are the demands upon the profession, and hence upon the schools. The school is brought into closer contact with the diverse conditions and problems of practice, and is becoming more closely identified with the profession.

But the school cannot control the conditions and opportunities of practice; it may in some degree anticipate them, and it must bring its ideals and teaching into conformity therewith. We do not deal altogether with ideal youth; few have ideal preparation and ideal capacity; the schools cannot all have ideal equipment or wholly ideal instructors; and even the ideal graduate would not find a world of ideal opportunities.

The situation presents some complexity; may we not also say perplexity? Are there not a few pertinent questions like the following:

May the equipment and teaching of the school be too complete, reaching too far beyond the *average* conditions and demands of practice, elaborating unduly details which are more exclusively in the domain of the practitioner?

Is the school sometimes attempting to cover too wide a field, assuming the work of a university while prescribing time and conditions sufficient only for a college course?

How far, and in what lines, is there a reasonable demand upon the schools for specialists?

We should not be agreed upon answers to such questions, even if they could be given. We are agreed, however, upon some first principles which always determine real progress, whether in the past or present.

First. Quality rather than quantity. The profession doubtless demands of the school that it shall at least

restrict overproduction by high standards of admission, by excluding all inferior capacity and by strict requirements of aptitude and high proficiency.

Second. Although the scope of the curriculum is now so greatly enlarged, *the proper work of the school must ever be upon the foundations*; upon those controlling principles, data, methods, manual operations, verifications and the common business transactions of engineering which underlie and sustain the broad superstructure of professional activity.

Third. The student should be made familiar with the best professional literature and all important sources of information; he must know how to make his knowledge and elementary skill effective in emergencies. For, after all the school can do, the man must continue to educate himself.

Finally, the school must give the man inspiration from the history, traditions, achievements and noble personalities of the profession, both past and present. By this means, and through the personal influence and example of his instructors, the student should grow into strength of character, firm integrity, and that high sense of professional honor which, amidst all temptations, will ever hold duty and truth far above any price.

DISCUSSION.

PROF. L. S. RANDOLPH said that he had listened with great interest to this paper, which gives a review to a considerable extent of engineering education, and it seemed to him to point the way for future progress. At first, the education was purely theoretical, then

came its application in the school directly to concrete problems. It seemed desirable to carry the latter further. The problems should include not merely the determination of important parts, but also a consideration of the cost, for that measures the success of any engineering problem. The speaker was very much struck with the author's remarks on architecture, and the relation of engineering to architecture, and this brought to his mind a remark which was quoted as coming from a celebrated architect, that the architect of the future must be an engineer. To-day on all sides, large buildings are going up which would not stand if constructed under former methods. Their cost must be within reason, and heretofore the method has been for an architect to employ an engineer, as one architect expressed it, to attend to certain details. Within the last few months, mention had been made of a large building which was designed by the engineer, an architect being employed to do the decoration, as it was expressed. The speaker looked with a certain amount of dread on engineering specialization. His own experience and observation led him to believe that there is danger of going too far. The author calls attention to one of the strong points in technical education, that it fits a man not alone for his own profession, but for others. Take, for instance, farming. A friend of the speaker who has had a good deal to do with it, remarked the other day that one cause of failure with so many farmers is that they know so little of engineering. There are so very many diverse interests in which technical education applies, that it seems a pity to confine a man in a college course to

one particular line. He never knows what his work will be when he graduates. The speaker remembered very distinctly his own particular experience. He had become interested in chemistry while at college, and had given particular attention to it; going into a testing laboratory, expecting to do engineering work, he was very much surprised to find that his only duties were making chemical analyses, and for eighteen months he worked as a chemist. One never knows what work the young man may enter upon, and it seems important to avoid as much as possible any specialization which will keep the student from knowing the elements at least, of other lines of his profession.

SOME NOTES UPON CIVIL ENGINEERING EDUCATION WITH SPECIAL APPLICATION TO JAPAN.

BY J. A. L. WADDELL,

Kansas City, Mo.

Much as the writer would like to write a paper upon "Engineering Education in Japan," which he was invited to do, lack of time has prevented his doing this. However, he is glad of the opportunity of making a short, informal address by dictation to his stenographer, upon the general subject of Civil Engineering Education, a subject in which, perhaps some already know, he formerly took the deepest interest. More than that, he can say truthfully that there is no subject, his own chosen specialty not excepted, in which he is more interested than in Civil Engineering Education. It is, in his opinion, the most important branch of our profession, for the reason that the development of all other branches is dependent upon it.

Unfortunately, for many years the practicing members of the profession have had a tendency to look down upon and sneer at the professors of civil engineering. Such a tendency exists more or less to-day, but by no means to such an extent as it did ten or fifteen years ago. Undoubtedly, the formation of this Society has had a great deal to do with the raising of its specialty in the eyes of brother engineers; and there is reason for hope that in years to come this Society will succeed in placing the professors at the head instead of at the foot of the engineering profession.

The time was when a man who could run a transit

without making mistakes considered himself superior to nine out of ten of the professors of civil engineering. That he was entirely wrong, goes without saying.

It is true that there has been a tendency among literary colleges, universities and even some technical colleges, to engage cheap men to fill engineering chairs. Such action, of course, must keep down the general status of the speciality, but time and experience will assuredly correct this error. The average professor of civil engineering is generally insufficiently paid, and that fact alone militates greatly against the high standing which professors of civil engineering ought to take in the community. Compared with those in other branches of the profession, teachers of civil engineering are paid but little more than half of what they ought to receive. This is probably because the professor's work is to a large extent a labor of love. Of course, one cannot object to such devotion to the interests of truth and investigation; nevertheless, "The laborer is worthy of his hire," and the engineering teacher will never be fully appreciated until he is properly paid.

Some ten years ago, there was published in *Engineering News* a paper by the present writer entitled "Civil Engineering Education," in which was outlined what was considered to be an ideal course in civil engineering. It has been a matter of great satisfaction to note from time to time that the developments in teaching civil engineering have been directly in the line thus indicated. The writer has for some time thought of suggesting to the Program Committee of this Society a condensation of this old paper and

making of it a new one to present to the Society for further discussion, together with a few ideas picked up in the last ten years of an active practice. His ideas of what a course in civil engineering should be are briefly as follows :

First. No really thorough course in civil engineering can be given in less than five years.

Second. Every student, before admission, should have had a thorough course in non-technical subjects, the broader the better. More especially should he be well drilled in his own language and literature, for the reason that in a technical course but little time is given to anything outside of the regular routine of mathematics and technics.

Third. The technical course ought to include a great many branches allied directly and indirectly with civil engineering, such as electrical, mechanical and mining engineering ; *i. e.*, the course should give the rudiments at least of all these subjects ; and, in addition to these, such studies as Geology, Chemistry, Physics, Lithology, Mineralogy, etc., should be taught at least in an elementary manner, and in such a way that the student will really know something about them when he gets through with the course.

Fourth. The amount of work in the so-called theoretical courses, such as pure mathematics, rational mechanics, descriptive geometry, etc., should be increased rather than diminished, as compared with the courses given in the best technical schools of this country.

Fifth. Graphics in all its branches should be taught much more thoroughly than is done in America ; although perhaps not so much time should be devoted

to it as is customary in European technical schools. If the student be taught to reason graphically, he will in his practice be enabled to eliminate a large amount of drudgery from his computations.

Sixth. Every student at the beginning of the course ought to be made proficient in the use of the slide rule.

Seventh. All purely technical courses should be made much more extensive than they are ordinarily given, and in each course each student should be required to make a complete design, with an estimate of cost, for some structure or construction, and said design should be made under the eyes of the instructor. There is a great deal of humbug in graduating theses. Quite often a student goes up to his final examination with a thesis prepared by somebody else. A single thesis in a four or five years' course is not enough, for there should be a thesis in each branch of practical engineering work, including, when practicable, surveys and other field work.

Eighth. Classes in engineering should not be too large. In the writer's opinion, an instructor cannot teach properly more than twenty men at a time, and a much smaller number would be better. This is because, to give the student the full benefit of the course, the professor should take a personal interest in all that he does, and should be his friend, rather than, as the student too often supposes, his enemy, whose sole object is to condition him and drop him out of the course.

Concerning these two methods of teaching, the writer can speak from experience, for he has tried both. At the Rensselaer Polytechnic Institute, where

he both studied and taught, the course used to be made unnecessarily severe, graduation from that institution being an extreme example of the "survival of the fittest." In the writer's class only twenty-four men out of sixty-six graduated, and in the class before that only eleven graduated out of the same number. Surely the dropping of five students out of every six indicated unnecessary severity. Of course such a method of instruction makes a great reputation for the institution, but it does not do the best possible thing for the student, who is paying a good price for his technical education. Many a good man who has been dropped from Rensselaer could, with a little help and encouragement from his professors, have taken his diploma and done credit later to his Alma Mater. In making such statements as these, there is no purpose of suggesting the lowering of the standard for graduation. On the contrary, it should be higher than ever, but instead of throwing unnecessary obstacles in the way of the student, he should be aided in every legitimate way to get through his course creditably to himself and to the institution. Again referring to the course at Rensselaer, it should be understood that it is referred to as it was some twenty years ago and not as it is to-day.

And now a few words upon the subject which was suggested, viz : "Engineering Education in Japan."

Early in 1882 the writer was appointed to the Chair of Civil Engineering in the Imperial University of Tokyo, and started work in September of that year. The subjects in the department were those pertaining to civil engineering proper ; that is, all allied subjects

were taught by the other professors, including pure mathematics and rational mechanics. This special department covered everything of a practical nature, such as surveying in all its branches, railroading, hydraulics, including waterworks, harbors, rivers and canals, hydraulic motors, arches, resistance of materials, roofs, bridges, including both substructure and superstructure, and sanitary engineering.

At the outset a trial was made of the old Rensselaer tactics, subjecting each student to a rigid examination every day, but it was soon found that this was unnecessary, and gradually the methods were changed until after a while there was no trace left of the old ones. Eventually the courses were given by laying out at the beginning of each course a certain amount of reading to be done in a given time, and letting the students set for themselves each day the amount of ground they desired to cover. At the hour for recitation the professor met the students and acted in reality as consulting engineer for the class, answering questions and asking others in such a way as to bring out all the more subtle points of the subject. In this way about three times as much ground was covered in a given time as used to be the case at Rensselaer.

Some one may remark that the course could not have been so thoroughly given, and that the students could not possibly remember as much as they would have remembered had the course been shorter and the drill more thorough. In reply to such an observation it should be stated that no reviews were ever given, and that the examinations covered the entire ground of the course without any set topics. The students

were expected not only to answer all practical questions which would be asked, but had to give mathematical demonstrations wherever such were included in the technical books that they studied. On a number of occasions it was necessary to mark examination papers one hundred per cent.; for said papers were absolutely without flaw, unless one were so captious as to criticise an occasional awkwardness in the English.

The success thus met with in teaching in Japan must be attributed to a great extent to the wonderful capacity of the Japanese student to imbibe ideas.

The students were the writer's friends, and are so yet. Most of them to this day write once or twice a year; and whenever there is any information of a technical nature that they cannot obtain in their country they apply to the writer for it, and it is generally obtained for them. There is no professional success which the writer has achieved that yields more satisfaction than this does; consequently it is easy to see why he is in such sympathy with the labors of this Society and to understand the reasons for the statement made at the outset of this address, viz., that there is no higher branch of civil engineering than the specialty of technical education.

DISCUSSION.

PROFESSOR T. C. MENDENHALL said that he could add but very little to the interesting paper that Professor Waddell had presented. It was perhaps but justice to say that what one can accomplish by a given method with a given set of students to deal with, is by

no means an index of what one can accomplish by the same method with an entirely different set of students to deal with. No one appreciates that, probably, more than Professor Waddell, yet he has perhaps intimated in this paper that he considers the methods that he pursued there very decidedly superior to any that he was accustomed to use at home. The fact is, as probably every one knows who has had to do with the instruction of Japanese students, that there are many conditions existing among them that are rarely found to exist among students in this country or probably in any European country. The speaker felt sure that Professor Gray, who was also his colleague in Japan at the same time, shortly before Professor Waddell was there, would agree to that. It is not safe, therefore, to decide that a method which fits those people is altogether the best for the young men here, the circumstances are so very different. Students in Japan are very remarkable. In the first place they come—they did come, and no doubt it is still the case—they come with a hunger for learning and with an anxiety to make progress and to grow and grasp and master everything which is within their reach, that is not equalled in other countries, and of course that has a great deal to do with the fact that Professor Waddell could be the consulting engineer of the class and the fact that they could make most rapid progress under such conditions. The author might find it impossible to make such progress in this country with a set of American students. In other words, while agreeing with him in every respect in regard to his statement as to Japanese education and

Japanese students, the speaker thought that if Professor Waddell had, since coming from Japan, taught some classes of American young men as some of the rest of us have done, he would probably still adhere to the more conservative methods.

PROFESSOR THOMAS GRAY said that he had very great pleasure in teaching Japanese students engineering for several years. He agreed perfectly with Dr. Mendenhall in his remarks with regard to the difference between a class of Japanese students and the classes in this country or the classes to be found in other countries. The Japanese student is especially attentive to the instruction given him, and there is never any question of discipline coming up in the Japanese class. The remark which Professor Waddell made in regard to some papers being marked a hundred because they were absolutely flawless, was a common experience. The speaker had found it necessary to mark many papers a hundred because the answers were given in precisely the same words which had been used when the subject was explained to the class. He was not quite sure how that was to be accounted for. He had been inclined to think, as the Japanese really committed so much to memory from childhood up, that it was no trouble for them to reproduce almost anything you told them. It is certainly very remarkable, the way in which they can absorb what is told them and reproduce it in almost exactly the same form in which they got it. The courses of study which are carried out in the colleges in which he was teaching were very similar to those which are carried out in Europe. The methods of teaching were also similar. He could say

also that not only was the method which Mr. Waddell tried successful, but other methods were also perfectly successful. All produced excellent results in teaching in Japan ; both lecture and recitation methods. It did not seem to matter much how one taught, providing the whole of the important part of the subject was covered, excellent results would be secured in that country.

AGREEMENT ON DEFINITION OF ENGINEERING TERMS.

BY THOMAS GRAY.

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The subject "Agreement on Definition of Engineering Terms" has been suggested as suitable for discussion by this Society. The present paper is intended only to bring the matter formally before this meeting and give an opportunity for interchange of views on the subject.

With regard to the mere form of definitions, it does not seem desirable to adopt perfect uniformity because the writer believes that variations in the mode of expressing an idea are often beneficial in assisting students to obtain a clear conception of what a term is intended to imply. It is perhaps strange, but it is nevertheless true, that a carefully worded and perfectly correct definition of a term or statement of a law or an axiom, which seems clear and simple to the author and to many readers, is yet very hard to understand by others who have been differently trained. A good illustration of this is found in Thomson's axiom in thermodynamics, sometimes called the second law. The statement is very carefully made by Thomson, and yet all the conditions implied are seldom appreciated by the student or even by authors and teachers. As a consequence we find the truth of the axiom frequently challenged. If any attempt is made to propose a standard dictionary of engineering terms, it would be well, after defining any important term or phrase, to give some illustrations of its application and historical development. In fact, the dictionary should

be an encyclopædia of terms giving such information as will enable anyone to express the meaning of the term clearly in his own words. While the form of words used in a definition need not be always the same, it is of great importance that the same idea should be conveyed by them. By this is meant that the sense in which terms are used and laws or axioms stated, should be uniform. There comes up at once the difficulty as to how this uniformity is to be obtained. Not only is the question of authority as to the meaning involved, but also that of a perfectly unmistakable mode of presentation. One society such as this might appoint a committee, and after great trouble and considerable expense adopt and publish definitions of the more important terms, but the chances are great that almost everyone else would simply ignore the whole thing. As a matter of fact, the work of a society committee has often less weight than that of a single individual. That there is need for some such compilation of definitions, covering the terms used in the different branches of engineering, is evident from the frequent discussions which arise as to the meaning of certain terms and the unsatisfactory characters of much of the information given in even our best dictionaries. That the dictionary fails to be perfectly satisfactory is mainly due to the fact that special knowledge is in many cases required to understand the definitions given, and space cannot be afforded to supply the requisite discussion even if a perfectly safe guide were to be found on the staff compiling the work.

There comes into discussions on this subject a curi-

ous mixture of ideas as to what ought to be, and what is, the meaning of a term. This is more particularly the case, perhaps, with single words such as stress and strain, resilience, coefficient, modulus and so forth. We find preconceived notions as to the meaning of the word, or a knowledge of usage in other branches of literature, or simply the unprecise popular usage coming in to make difficulties. Take the terms stress and strain just mentioned. As a result of the fact that in popular language, and often also in technical literature, strain means either the deformation of a body or the system of forces which produces or is produced by it, Rankine was led to introduce the word stress to represent the system of elastic reactions caused by a change of shape in an elastic substance. Strain was then used to signify deformation. Rankine's lead was followed by others, one of the first and more important cases being in Thomson and Tait's treatment of elasticity. In this case, however, it may be remarked, the word stress represents the applied force equal and opposite to Rankine's elastic reaction. There may possibly be room for some difference of opinion as to whether the sense in which these words are used is perfectly consistent with their previous meaning, but that is a small matter. The most important question is, do we require two terms, and if so do those given satisfactorily fill the bill? So far as the necessities of the case are concerned, it may be possible that, so long as we keep to such applications as are common in practical work, the double meaning of the word strain gives little difficulty, and the beautiful indefiniteness of the word may even be advantageous. When we try to discuss prob-

lems in the theory of elasticity, however, it becomes absolutely necessary to make a clear distinction between quantities of different kinds.

The words stress and strain have been taken for the purpose of illustration, partly because nearly everyone is familiar with the discussions which frequently arise concerning them, and also with the very loose way in which they are used. There are many other terms used in as indefinite a manner, but it is not necessary to multiply examples. Neither does it seem necessary to bring into this discussion any question as to the actual meaning of particular terms. A slight or even considerable difference between the meaning of a word in a particular branch of science and its ordinary everyday meaning is not a serious matter so long as we maintain perfect uniformity in its scientific use. When introducing new terms it is, of course, well to avoid, as much as possible, the use of common words in any but their ordinary meaning, but there are also some advantages in using words which from their ordinary application suggest at least the character of the physical quantity to which they are applied. One great difficulty in this subject is just this introduction of new terms, and in my opinion it is better to go to a little trouble to use language already familiar, even if it be necessary to use a sentence where a word would do if we had one to stand for that sentence. A special vocabulary and a list of definitions at the beginning of a book is an abomination to most people and, although it saves space, it is apt to render the book much less attractive and harder to read than if it were twice as long.

Standard works on engineering agree fairly well in their use of terms. There are, of course, a number with regard to which there is diversity of usage; for example, we sometimes find in one work the term coefficient of resilience, while in another the same thing is called modulus of elasticity. Again, there is difficulty with terms like isotropy and homogeneity and so forth. A little care would avoid such trouble, because in most cases the words are made to appear synonymous, not so much from want of knowledge as from carelessness. Generally, however, in the better class of books, a careful reader will find no difficulty in understanding what the terms imply, although there may be some annoyance from the fact that in his own vocabulary a different term is used. Societies of teachers can do a great deal to produce uniformity in the use of terms and also in the simplification of definitions and methods of treatment, if only some guide can be got, and together with that, a determination to bury personal prejudices.

When we turn to popular engineering literature and to journal articles we do not find anything like agreement in the use of terms. In fact, a great deal of this kind of literature is more an obstacle than a help to progress. We suffer from a superabundance of journalistic literature. So much is printed that, in order to keep up the quantity, almost any quality has to be used. It is doubtful whether anything but slow development can be looked to for a cure in this direction. There is no doubt but that the rapid spread of scientific education will quickly have its effect in raising the standard of popular literature. It is probable,

however, that it will always be those that know least who are most anxious to write, and therefore that the standard will have to be raised by the discouragement of poor publications.

There is one direction in which a good dictionary of scientific and engineering terms would be of great service. That is in the writing and interpretation of specifications. If it were possible to refer for the interpretation of all terms to a standard work, a great many troublesome disputes might be avoided, and a great deal of time might be saved which is now used in carefully safeguarding the statements made in the specifications. Such an application would, besides the convenience of making uniformity, bring the terms in their proper meaning before practical men and hence, through the workman, into practical use.

DISCUSSION.

PROFESSOR J. GALBRAITH remarked that the subject of this paper overlapped, to some extent, the work allotted to the Committee on "Uniformity of Symbols for Engineering Text-Books," the meanings of terms having to be considered in connection with the question of notation. The paper instanced stress and strain as examples of words whose usage in scientific works is in a very unsettled state. The speaker might mention another word in the same category, a word which of all words one might expect to be used in one sense only, viz., the word unit. In the expressions "unit length," "unit mass," "unit velocity," meaning, e. g., a foot, a gramme, a mile per hour, respectively, the word unit is used in the correct sense. Can this be

said of its use in the expression "unit-stress," which is so frequently found in modern engineering textbooks and specifications? The engineer specifies that the "unit stress" shall not exceed ten thousand pounds per square inch; that the unit stress may range from five thousand pounds in tension to five thousand pounds in compression, etc., etc. Imagine him specifying that the unit length shall not exceed one foot, or that it may be anything between one foot positive and one foot negative. The absurdity is spreading. Authors, encouraged by the success of "unit stress," have begun to try the effect of "unit strain" on the engineer. The matter is worthy of receiving some little attention from the unitary doctors.

PROFESSOR J. M. ORDWAY said that he had occasion recently to examine a new work on the chemical applications of electricity. The terms "ampere" and "volt," which occurred in the first part of the book, were defined in terms of each other. There was no absolute definition. The case was just like saying "a foot is twelve inches; an inch is a twelfth of a foot." It was not until the middle of the book that there was any idea given as to how the quantity of electricity was to be determined. It is quite important, whatever definitions we give, that they should be given in terms that have been previously defined.

PROFESSOR E. A. FUERTES said that it is not only in the definition of engineering terms that there is a vagueness and confusion. The lack of uniformity of meaning exists in engineering specifications for the construction of works, both as to volumes and weights, as well as to quality of work. Thus, a mason may bid

\$2.50 for a "perch of rubble masonry" in New York, containing, say, 16½ cubic feet, and were he to bid for the same unit of work in Pennsylvania he would be required to build a larger volume for the same price. Then, again, the term employed to describe the nature of the work is equally vague. There is no authoritative definition of what "rubble work" should be, and although we may find, in the specifications for the Croton aqueduct, rubble ranged or levelled, and so forth, and so forth, a contractor bidding from a distance is not able to know what is wanted, unless direct reference is made to work already existing. Then there is nothing definite about the meaning of the words "crandalled," "patent hammered," "pean or bush hammered," and so forth, and so forth; and the same kind of surface work may be called by different names in different States, or different kinds of work may have the same name in other States.

There is a complete lack of uniformity and of that exactness in the definition of engineering terms that the advance made in our profession should already command. This vagueness of definition seems to be purely inherent to our country, probably on account of the fact that, even at the present day, we are in the habit of importing skilled laborers of various nationalities who introduce their own terms, and these are subsequently anglicized or changed in States remote from each other.

It seems desirable that the Committee on Uniformity of Symbols should keep this matter in view, for it is likely to become a fruitful and useful field in which to strive for the uniformity of standard terms

in engineering nomenclature. While it is not probable that complete success will be attained at once, a very great deal can be done through the weight and influence of this Society to bring about this result, especially since, in addition to the fact that we can exercise professional pressure in various directions, we are charged with a duty of teaching those nomenclatures to future engineers. The seed planted in the class room will eventually bear fruit in the generalization of uniform symbols, definitions and specifications for accurately describing work.

PROFESSOR THOMAS GRAY said, in regard to Professor Galbraith's remarks on the unit, that the examples given by him are, of course, wrong uses of the word "unit" in complex quantities in which some one quantity necessary to make the specifications complete is omitted. There are a very great many examples of that kind of mistake, particularly in journalistic literature, and it was largely that kind of thing that was referred to in the paper when speaking of journalistic literature. There is an opportunity for reform in this matter while trying to secure uniformity. In regard to the remarks by Professor Fuertes, the speaker had particularly in mind just the same thing when he stated, at the end of his short paper, that there would be great advantage in securing uniformity in regard to specifications for contracts. The want of definiteness in this direction, which has been pointed out more fully by Professors Galbraith and Fuertes, shows the great advantage there would be in having some definite uniformity for everything in regard to contracts, so that it may be known exactly what is to be done when an agreement is made to do it.

THE ELECTIVE SYSTEM IN ENGINEERING COLLEGES.

BY M. EDWARD WADSWORTH.

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It was my privilege to present, for your consideration last year, a paper on the elective system as adopted in the Michigan Mining School ; it is now my purpose to continue this subject by presenting some further particulars, and pointing out the conditions under which this system might with great advantage be introduced into other engineering colleges.

To establish a clear understanding between the auditor and the author, it is desirable to divide the matter up into heads which are regarded as cardinal points in the argument.

I. ENGINEERING IS A LEARNED PROFESSION.

This will probably be admitted without discussion ; hence it clearly follows that studies forming an integral part of the course in all engineering colleges, are just as truly professional studies as are those given in schools devoted to Theology, Law and Medicine. Those who follow the last named professions have certainly not excelled the engineer, if they have equalled him, in the task of promoting the happiness, welfare and morality of mankind ; nor can it be proven that success in either of these professions requires deeper study, higher intellect, more experience with men and things, or better balanced judgment, than is needed for the successful presentation of engineering projects. Why,

then, does the public at large hold the engineering profession inferior to the others just mentioned ? The answer is because we ourselves have set them the example, and they accept the engineer at our valuation. Educators have, unconsciously perhaps, but none the less truly, proclaimed their own conviction of the inferiority of an engineer's mental needs and equipment by the introduction and continued retention of

II. NON-ESSENTIAL STUDIES IN ENGINEERING COURSES.

This mistake naturally arose from the fact that the early engineering schools or courses were planned in the now clearly erroneous assumption that their training

- must include a so-called liberal education, or else must prove itself to be the equivalent of the classical courses then in vogue. Further, most of these early engineering courses were grafted into older institutions, under the control of a literary or classical faculty, men whose very training and success in their chosen lines disqualified them to perceive that the study of engineering, if properly conducted, affords just as rigid, logical and powerful a mental training, as can be obtained through the study of any other subjects whatever. Nor has the day yet passed when men can be found who strenuously maintain that such utilitarian studies tend to warp and narrow the intellect; and in their laudable efforts to overcome an imaginary evil, they persist in injecting into engineering courses such subjects as Christian Evidences, British Essayists, History of English Literature, Ethics, Hygiene, Greek, etc. That these subjects are worthy of study and afford valuable educational training is freely conceded ;

that they excel engineering subjects as tools for sharpening the intellect, or that they have the slightest bearing upon the professional training of an engineer, or any legitimate place in an engineering course, is emphatically denied. If the engineering faculty deems a knowledge of such subjects essential, it should demand it as an entrance requirement of the engineering college. To include them as a part of a technical course is as illogical and unseemly as to demand that law students pursue a course on pumps, or medical students one on roof-trusses, or theological students one on thermo-dynamics. The engineering faculty, and they alone, are the parties competent to formulate the list of studies for engineering students, and their decision in such matters must be final, if engineering courses are to be freed from driftwood and barnacles.

III. THE NATURAL SEQUENCE OF STUDIES MUST BE OBSERVED.

It is objected by many (1) that under the elective system the student will receive only a disorganized course, and (2) he will finally graduate with a training which is insufficient, because it lacks both depth and comprehensiveness. Neither objection is sound, if the course is in competent hands. The professor of each branch unquestionably knows what subjects a student must have mastered in order to profit from his own instruction ; hence, if these are rigidly demanded, his students must necessarily have received a systematic and thorough training in everything having a real bearing on any work they elect to take up. Strict observance of the sequence of studies will, with mathe-

matical certainty, force each student to go thoroughly over every subject preparatory to every other subject elected ; hence a disorganized course becomes impossible. It thus appears that, by this system, depth is not sacrificed, but rather increased.

Lack of comprehensiveness is easily and effectively guarded against, by demanding for graduation as many courses as a good student can successfully carry in the time usually available for a college course. Indeed, if the natural sequence of studies be rigidly observed, it is advantageous and perfectly feasible to throw down the artificial barriers that have grown up between the different branches of engineering, and thereby allow the students to enter upon a general engineering training, without any sacrifice of thorough work, or any friction between various departments. Students can select courses in harmony with their dispositions and abilities ; the differentiation will take place naturally. While the degree will not mean that all have taken the same studies, it will mean that every study has been prosecuted with success (which is never the case with a rigid or optional system). Further, it will mean that the student has received a better training for his life work than can be given under any rigid or optional system. Quality, not quantity, is the distinguishing feature of this plan.

There is no reason whatever why the elective system should be confined to engineering colleges alone among professional institutions. If the sequence of studies, which is to the elective system what the key-stone is to an arch, is rigidly observed, the system can with advantage be introduced into Law, Medical, Theological or other professional colleges.

IV. THE ELECTIVE SYSTEM CLEARLY SHOWS UP INFERIOR TEACHING, SUPERFLUOUS SUBJECTS AND INCOMPETENT PROFESSORS.

As each professor rigidly demands proficiency in all branches preparatory to his subjects, every student in a class must in a measure serve as an exponent of the ability, thoroughness or honesty of such other professors as have had charge of his previous studies. Any evidence of general inferiority in training in any one subject is quickly detected, and the remedy should be promptly applied.

Everyone who has had any experience under the rigid system knows fully that the range and nature of subjects in such courses are so broad that no pupil is endowed with sufficient talent to excel in all these studies, while the majority of students attain only a medium standing in various subjects. Excellence in some branches is therefore considered to atone for deficiency in others, and the student is passed. Such a procedure is neither necessary nor permissible under the elective system, and if resorted to cannot fail to expose the instructor responsible for it.

Should a professor introduce courses foreign to the work of the school, the fact is quickly made apparent, because no other professor prescribes such courses as preparatory to his own, nor do the students elect them. Hence, this system does away completely with all padded courses, incompetent instruction, or irrelevant matters given merely to fill in a certain amount of time. It makes such instruction serve as a check on the proficiency of the others, produces a coördinate system of studies, and renders possible educational

results which under the old systems would demand a much larger faculty.

V. THE ELECTIVE SYSTEM IS THE ONLY ONE WHICH
CAN MAKE FULL PROVISION FOR THE DIFFER-
ENCES IN TEMPERAMENT, TASTE AND TAL-
ENTS, WHICH MUST ALWAYS EXIST BE-
TWEEN THE VARIOUS MEMBERS
OF THE STUDENT BODY.

The province of an educational course is to develop and sharpen the intellect; it cannot create brains, nor can it by any method whatever eliminate those differences in men which are implanted in them by the Author of Nature. It is difficult to understand why the attempt should be made to perpetuate an educational bed of Procrustes; for the writer maintains that this very thing is attempted when, contrary to the teachings of Nature, it is insisted that students be divided up into arbitrary classes, every member of which must be forced to go through exactly the same scheme of studies without reference to his natural tastes and abilities. The results of this procedure are too well known to need further comment here.

Under the elective system the student selects that work for which he has been properly endowed by nature; he takes far greater interest in it, and the results are deep and permanent. So marked is this that no instructor in the Michigan Mining School now hesitates to demand of his men far higher and better work than even the most sanguine could ever hope to get under the old rigid system. Even if the elective system does demand higher work in each branch, and

a more proficient preparation for each study, the student himself readily sees the object and justice of each requirement, and cheerfully accepts an obligation which carries with it freedom in choice of studies and avoidance of those non-essential. All this acts like oil upon the machinery, and enables the product to be turned out with little noise, friction and wear and tear.

It is frequently urged that a student is not competent to draw up a proper list of electives. If this statement be true, does it not carry with it the inevitable conclusion that he is even less able to select his studies for four years, before he has had even a day's experience in the course? Is not this exactly what he is required to do, when he is held to a rigid or optional system?

But experience shows that this statement has no basis in fact. The natural sequence of studies guides the pupil when making his selection, and, assisted by advice from his teachers, which is always freely given, he rarely goes astray, unless his abilities and tastes are misjudged. This rarely happens and the mistake is easily remedied. No such means of rectifying even slight mistakes exists under a rigid or optional system. It is necessary to take the "system" and take all of it, or to take nothing. It may not be amiss to call attention to an exactly parallel case in actual engineering practice. Those engaged in electrical work know that a comparatively short time ago every electrical plant, from dynamo to lamps, was a representation of some "system," and it is likewise known that not one of those systems was free from many defects in details.

To-day all this is changed. An electrical plant may represent the product of a dozen or more different makers or "systems," because each part has been selected solely on its merits for the particular purpose in view. It represents one case of the beneficent workings of the elective system in the practical affairs of life.

Under the rigid system, a student who finds that he has misjudged his abilities must either struggle through in some way, thereby building for his future a structure which is rickety and valueless, or he must quit the course altogether, receiving, as a reward for his work up to date, only a practically worthless foundation for a mental structure which will never be completed. In the case of a similar mistake under the elective system, the student may indeed have to change some of the lines of the edifice, but little of the material is wasted, since it can nearly all be used again in a new structures designed with a better knowledge of his capacity and needs.

Since engineering is largely a matter of economics, is it not wise to have the student make the first application of this principle when expending his own energy and time?

VI. CERTAIN CONDITIONS ARE ESSENTIAL IF THE ELECTIVE SYSTEM IS TO BE A SUCCESS.

It must be clearly recognized that every educational institution has its individual peculiarities; hence before undertaking the introduction of a new system, or a modification of an old one, every school must make an exhaustive inquiry to determine the relations be-

tween the proposed course and its environment, constituency, faculty, trustees, equipment, object, etc. That scheme which is most in harmony with these should be adopted, and in determining which one most nearly meets the required conditions, nothing is more necessary than a liberal use of that very rare commodity, common sense.

It is surely unnecessary, when addressing a body of engineering educators, to point out the uselessness of mere copyists or servile imitators; temporary success may crown their efforts in some cases, but not in one like this, because in every problem the requirements are so diverse. In every case the scheme must be worked out anew, in every detail, from the very foundation.

If the writer were asked whether he would introduce into any other school in America the elective system as now adopted in the Michigan Mining School, he could conscientiously give but one answer—most emphatically, “No.” The reason for this is that, while the system seems perfectly in harmony with all its needs, this school is unique in its nature, and its counterpart is not to be found elsewhere in this or any other country. While its system and methods are the proper ones for this school because they were specially designed to answer its wants, they will no more meet perfectly the diverse necessities of other schools, than will one prescription cure every disease.

Notwithstanding this, it is firmly believed that the logic of the system is perfectly sound, and contains more largely than any other the elements of success for any school, if its details are carefully and consci-

entiously worked out so as to meet the peculiar needs of each institution. It seems impossible for any educator to study exhaustively the history of education and the spirit and needs of our own time, and then fail to draw the conclusion as stated to the Society last year, that the elective system is the coming system, and that sooner or later it will find its way into every institution of higher learning in the land.

Every educational scheme, and the elective system more than any other, demands for success that schools be conducted on sound business principles, the most important of which are here mainly condensed from the writer's first "Report to the Board of Control of the Michigan Mining School."* The governing board must be composed of experienced, able, judicious and conscientious men ; they need not of necessity be educators or engineers, but they should have the wisdom to perceive that the successful direction of a higher educational institution requires experience and ability on a par with that demanded in any other business or profession. They must realize that no success can crown their efforts unless they clearly understand that their duty consists entirely in formulating the objects of the institution, providing the means to reach those objects, choosing an able and discreet Director or President, and seeing that he attends to his duties. Assumption of any other power is mathematically certain to cause friction and throw painful obstacles in the way of progress.

It is clearly evident that a board will be more excellent in proportion as its members are graduates of

* Pp. 70-80.

higher institutions of learning, and if possible, one similar to that over which they are presiding.

The success of the institution depends largely upon the chief executive officer and the faithfulness with which he is supported by the board and faculty. The president need not of necessity be an engineer, but it is absolutely indispensable that he be an able and experienced educator, a man of broad gauge, liberal spirit, unbounded energy, perseverance and firmness. To him should be left, without any interference whatever, the carrying out of the plans formulated by the board, and he should be held strictly accountable for results. Nothing short of incompetence should be deemed a sufficient reason for interfering with his plans.

The president must make a study of the institution as a whole ; formulate the results to be reached by each official of the school in order to carry out the general scheme ; see that these results are obtained ; be empowered to discharge, without recourse to others, any official found to be incompetent. He must allow each of his associate officers full liberty to reach in his own way the results demanded of him, rigidly abstain from interfering with his work, and aid him whenever possible. With a suitable president, competent faculty and close adherence to these methods, it is possible to introduce an elective system which will meet the needs of the student and every live professor, and show up incompetents. It will force the removal of that kind of driftwood which litters up so many of our educational institutions, simply because the president is not granted the proper authority to handle such material and lacks the backbone to demand its removal.

by the board. Unless someone oversees the instructors and is empowered to remove incompetents, success will not be likely to crown any scheme, and least of all the elective system.

VII. THE ADVANTAGES OF THE ELECTIVE SYSTEM.

They may be briefly enumerated as follows :

(a) It lightens the labor of the instructors, *i. e.*, removes much of the drudgery, makes the work far more a labor of love, and enables each one to give as extended a course in his department as he wishes, without interfering with another professor.

(b) It greatly reduces the friction between faculty and students, almost does away with faculty meetings, and renders the necessary regulations few in number.

(c) It renders examinations almost unnecessary, grades the student by his daily work, removes the padding of courses, shows up inefficient teachers, and allows the professors and the institution to get rid of incompetent pupils with almost no friction.

(d) It results in better and higher work in each subject, and develops the best that is in each student.

(e) It is more economical, both in money and time, than either the required or optional systems, *i. e.*, a smaller faculty accomplishes the same results.

(f) It enables an institution to keep pace with the rapid development of the various branches of engineering, without the introduction of new faculties and new degrees with their attendant evils.

(g) It serves as a safety valve for the students' pent up energies, and almost does away with class rebellions, especially those due to some particularly obnox-

ious professor, or to the suspension of some popular student.

(h) It does away with the practice of hazing and most of the other disgraceful customs of students in educational institutions ; it renders the student more manly, and in a professional school allows a man to attend to athletics and his studies, without that demoralizing sacrifice of truth so fearfully prevalent.

(i) It proclaims to the public, and with perfect truthfulness, that not only has the student "gone through" certain studies to obtain a degree, but that each of those studies has "gone through" him ; in other words, that no student has been allowed to slide through some studies in which he was weak, because there were others in which he was proficient ; nor has he been graduated simply because of his excellence in athletics.

(j) It unites into one harmonious whole the studies that are usually classed as undergraduate with those that are called graduate, and leads the student to consider them all as desiderata for his work. It broadens his field of view, inclines him to pursue further study, and diminishes his tendency to contract the megacephalous disease.

VIII. EXPERIENCE IN THE USE OF THE ELECTIVE SYSTEM AT THE MICHIGAN MINING SCHOOL.

When the writer assumed the position of Director of the Michigan Mining School, nine years ago, the institution was in its infancy, and no systematic course of instruction had been laid out. The rigid system usual in engineering schools was the only one then

available, and it was accordingly introduced. The rapid development of the school soon pushed this system to its ultimate results, namely, the wishes of each member of the faculty as to the work he thought should be given in his department were gratified. There resulted, in consequence, an engineering course which could be successfully coped with, only by one exceptionally able both mentally and bodily. Seven to nine hours daily were needed in the class-room and laboratory, and all preparation for this work had to be done in outside hours.

Every instructor realized that the system was crushing under its own weight, and that prompt relief was imperatively necessary. When casting about for a solution of the long foreseen difficulty, the Director, among other things, interviewed each member of the faculty, separately, as to his views on the desirability and practicability of an elective system. He properly considered that such views would be more than usually valuable, since the faculty then contained men who were not only experienced in the methods and systems used in schools in Germany and in the Universities of Harvard, Pennsylvania, Wisconsin, Ohio and Georgetown; Colby and Bowdoin Colleges; and the Michigan Agricultural College; but they were also familiar with the methods employed in Columbia, the University of Michigan, the Massachusetts Institute of Technology, and in most of the other leading schools of the country. The consensus of opinion was that such a system, while advantageous in a literary institution, presented insurmountable obstacles to its introduction in a technical institution like the Michi-

gan Mining School. The Director, however, saw no other solution for the difficulties then encompassing the course of study, and, notwithstanding the discouraging outlook, determined to test the practicability of laying out a suitable scheme; from time to time he consulted each instructor as to his wishes in all matters relating to his department. After several months labor the details of the plan were finally worked out, obstacles surmounted, conflicting interests harmonized, and the completed work submitted to the faculty and the board. It was promptly and unanimously adopted by both bodies, and has proven to be the greatest single advance the Michigan Mining School has ever made.

The faculty meetings have been reduced from one or more weekly to five in forty-five weeks, and, unless some emergency arises, one or two meetings a year will in the future be all that will be necessary to transact the business that is required of the faculty as a body.

The system has also brought about a simplification of the other work and enables it to be rapidly done, because the Director is charged with the duties that usually devolve upon a faculty, and because each professor has absolute control over his department and the students in his classes. The professors in charge of departments are responsible to the Director, while each of the other instructors is directly responsible to the head of the department with which he is connected.

The regulations of the school have been greatly reduced in number, and so arranged that the student himself is specially interested in seeing that they are observed, since if they are not, his own act takes him

out of the institution and closes the door behind him, in most cases without the intervention of the faculty or Director. Everyone who has debated long hours over the case of some student, whether it was "to be or not to be," can realize what a relief such automatic action is for a long suffering faculty. These changes have all grown naturally out of the elective system, with the result that the Michigan Mining School has had one of the pleasantest, most profitable and harmonious years it has ever experienced, although it has never developed enough disturbance in its history for the newspapers to take up its discussion. Not a single professor or student desires to, or would go back to the old system and while further experience will undoubtedly indicate various modifications of details, it can certainly be considered at this time that the elective system is an unqualified success.

DISCUSSION.

PROFESSOR DEVOLSON WOOD wrote that he thought elective studies in engineering courses are, as a rule, demoralizing, that they lower the standard of mental discipline, are costly to the institution, and are unnecessary. This is no reflection upon an institution which can equip and maintain different courses, which courses, it is presumed, are elective. As there are exceptions to all rules, so in this case the Michigan Mining School may have found advantages even if it has not yet discovered disadvantages.

A graduate, after years of professional practice, said, "A student should understand at the outset that he is to pursue any study that is required of him ; for he

may find that the first thing he will have to use when he leaves college is that which he most despised when in it." Lay greater emphasis on the "how" and on the "what" is studied. One straight, solid, thorough course without electives will make stronger men than one weakened by electives.

PROFESSOR J. GALBRAITH said that he had listened with great interest to the paper. The difficulties mentioned in connection with the ordinary system are more or less acknowledged by all. The great amount of work required of a student under this system, and the undue proportion which the dry and apparently useless work bears to that which is interesting, make the curriculum to some extent repulsive. The desire of individual professors to aggrandize their own departments and to arrange the curriculum to suit their special requirements may in some cases produce a bad effect. The speaker had hoped that the paper would make clear a method of avoiding some of these difficulties, but was obliged to confess that he did not see the solution in what had been said. It appeared to him that the only persons who are qualified to lay down a curriculum in the professional courses of a technical college are the members of the faculty, and they require to bring their combined experience and knowledge to bear upon the problem. The student certainly is not in a fit position to select the various subjects leading to a professional degree, and decide the order in which they are to be taken. Of course, if an institution decides to give its degree in one subject of study as distinguished from a professional department, it would be quite a proper course for the student to

consult with the professor of that subject as to the preliminary studies that might be necessary, and to follow his advice.

Even this is very far from being an elective system. The professor makes practically a fixed course; just as in the case of graduation in a professional department the faculty lay down a fixed course, and where the choice of the student comes in after selecting his subject of graduation is not very clear. No practical method can be devised of making the individual studies in a professional course elective if the degree is to be worth anything, and the speaker did not think that the term "elective system" ought to be used where this is not done.

PROFESSOR WADSWORTH stated that there had not been the slightest lowering in the work, but instead of that a very decided raising. The professors of to-day demand of their students in the Michigan Mining School, that which not one of them would have dared to demand the year before, simply because the burden then was too great; the men could not stand the strain of so many subjects as those demanded by the required courses. In his own classes he had done work that he was ashamed to do, simply because he must do it or the men could not by any possibility get along. The burden was beyond that of human endurance. The student now takes fewer subjects in the same time, but does higher and better work.

If modern languages, together with everything else that has been asked for from time to time, are made a part of the engineering courses, what opportunity is there for sufficient, or even for any, real engineering

training? If engineering studies are necessary for a man, it will not do for him, in his engineering course, to spend most of his time on modern languages and on a variety of unprofessional studies that might be interpolated in an elective course. These studies should be preparatory.

The elective system does require of a man that he shall take a definite amount of work in order to graduate; he must take the same amount that is required of him to graduate in a prescribed course, and it must be strictly in the line of professional studies. The idea that, in an elective system, a man can graduate if he has spread himself over any given number of studies without regard to their relations, is a thing that exists in no elective system outside of a kindergarten. It cannot exist. No man can study calculus until he has studied algebra. The sequence of studies must be followed, and the moment this is done, the student finds himself forced, practically, into a proper course of study. The elective system is a natural and logical system and it reaches the ends that every one has been hoping to obtain in the required courses. It removes from each student's selected course the special studies in which he cannot naturally succeed.

PROFESSOR GALBRAITH suggested that in that case the course agrees with ordinary practice, but contains only what are considered necessary subjects.

PROFESSOR WADSWORTH agreed to this, saying that for each student his selected course became for him a fixed course—fixed by his natural tastes and abilities, and not fixed by a faculty who knew and could know nothing about him.

He continued by explaining further the operation of the system described. When the professor of hydraulics demands of a student a certain amount of study, he does not say that the student should have everything in the curriculum, but he says that the student who comes to him shall take calculus, shall take analytical mechanics, shall take physics, shall take chemistry, or whatever studies he wishes. The student, when he enters upon his course, knows that if he is to take hydraulics, he must prepare himself accordingly. If he wants metallurgy, the professor has laid down the ground previously which he must cover to take metallurgy. He cannot graduate under one professor and follow only one professor's course, for no three professors even can teach enough subjects to give a man his degree. The student can, if he wishes to do so, on one hand devote his time more particularly to metallurgy, chemistry, and geology as applied to mining; or, on the other hand, to the civil engineering or mining engineering sides. Or again, he can give most of his time to mechanical engineering or electrical engineering as applied to mining, and give less to the metallurgical and chemical sides. In this way he can follow his bent of mind and tastes; for as the individuality of the student varies, so he can modify his course; but he cannot graduate with an inferior training. The training is deeper and more thorough than it is in the required courses. The student may not take as many studies, but he does better and more thorough work.

There seems to be an inclination to make the criticism that it is impossible for a student to choose his

course wisely for simply one year, and yet he is ordinarily required to choose his life work for four years; that excites no comment; that is considered perfectly proper. If a man can enter a school before he has ever had a year's experience in any professional training, and select his course for four years, is he incompetent to choose it for only one year? That does not seem logical. With a knowledge of the sequence of studies, and under the guidance of professors, the speaker believed him capable of choosing and choosing well.

There is a difficulty, and a very serious difficulty, in the elective systems in many of the literary colleges; and that difficulty will arise in the engineering colleges unless there is a controlling supervision. That difficulty is the introduction of "soft" courses. The faculty must be under such authority that the moment any member undertakes to bid for students by giving "soft" courses, there will be a certainty of his going out of the institution. This is absolutely essential. No good system of any kind, required or elective, is possible unless incompetent professors are quickly dispensed with. The president, or whoever is in charge of an institution, must have backbone and authority enough to say that such men must go. This is particularly true with the elective, and ought to be made true of every system.

PROFESSOR H. S. JACOBY desired to ask a question as to whether there had been in the writer's experience an indication of a disposition on the part of any student to choose too one-sided a series of subjects.

PROFESSOR WADSWORTH replied that there had been none so far, perhaps because the system is guarded so that a student can not very well do this.

PROFESSOR JACOBY said he had a great deal of confidence in the ability of young America to choose very many more things for himself than he is often given credit for, and therefore had not much fear in that direction, and he felt very anxious to ask the question to more authoritatively learn the writer's ideas upon it.

PROFESSOR STORM BULL expressed, as his understanding of Professor Wadsworth's practice, that he allows the student to say whether he wants to study English or anything of that kind.

PROFESSOR WADSWORTH explained that, in the elective system described, the studies are limited to professional studies. English and similar studies are preparatory. These are not in the engineering curriculum. With free opportunity for the student to choose from modern languages and many other non-professional studies, in connection with his engineering work, nothing can be done with an elective system and obtain a high grade engineering course. The student will not be properly an engineering student. He will become a classical or a literary student, as that is the line of least resistance.

The system of electives commences in the Michigan Mining School at the beginning, *i. e.*, with the freshman, immediately upon his entrance.

PROFESSOR BULL asked what was required for admission, whether either English or foreign languages?

PROFESSOR WADSWORTH answered that the requirements for entrance with the former rigid courses had been somewhat peculiar. What had been then required, and what is required now under the elective system, are somewhat different things. The State

schools of higher education have a certain relation to the high schools; and there is now required a regularly established and satisfactory course of study in the high schools, if their diplomas are to be accepted for entrance. A special four years' course of study has been laid out by the Michigan Mining School, and recommended for the high schools to follow if they wish their diplomas to be accepted. This course includes English literature, the French and German languages, physics, political economy, rhetoric, logic, zoölogy, botany, astronomy, trigonometry and various other studies, such as in the old days constituted much of the old fashioned college course outside of Latin and Greek. French and German are carried through the four years. Formerly, under a special certificate for admission to the Mining School, only the mathematics, physics and astronomy were demanded as preparatory to the professional studies, somthing the same as is similarly the case in a law or a medical school ; that is, there was required algebra through quadratic equations; arithmetic with the metric system ; geometry, plane, solid and spherical ; physics ; elements of astronomy, and book-keeping. Book-keeping was required simply because in mining work the students ought to understand mine accounts.

At this time, if a student will satisfactorily pass an examination at the Mining School in the subjects named above, he will be admitted. The situation is peculiar ; everywhere in the land, and particularly in a mining district, there are a great many young men who have gone into practical business when they were about fifteen or sixteen ; later, when they have arrived at the age of eighteen or twenty, or

twenty-five, they have a desire to obtain an education. The high school tells them, "You must come to us four years, then you must go to some other institution three or four years to obtain your degree." This is a virtual embargo on these young men. They often have great ability; they work hard and they make the best students. Therefore these men are informed that if they will come to the Michigan Mining School, after a two years' special course in the high school, and also after they are nineteen years of age, or else will come to the institution and pass its examination in the special subjects above named, they will be allowed to enter. No difficulties have thus far resulted to the Mining School from doing this. Experience has shown that graduates of the high school do just as well in the higher and harder work, and stand the wear and tear of an engineering professional training in the Mining School, as well as do the graduates of colleges and universities; oftentimes better, for the simple reason that the majority of the latter have been trained to memorize, and do not know how to reason. They have committed to memory Greek and Latin grammars and works of that kind, so that they have unfitted themselves to think over practical questions. The instruction given students at the Michigan Mining School incorporates a vast amount of practical work as an application of the principles taught.

PROFESSOR W. F. M. Goss said that if he understood the paper, it stated that the elective system would do three things: It would avoid the overcrowding of courses; it would operate to cut out subjects which have no real value, if any such exist; and it would serve as means by which undesirable students

may readily be sent away. Since these are all matters which under any system of courses are well within the control of the faculty, the real claim seems to be that the elective system will somehow protect the faculty against itself. He thought that the average faculty needed no such protection.

PROFESSOR WADSWORTH replied that the three things mentioned covered a part of the advantages, since experience shows that the average faculty fails to accomplish these objects with a required course.

PROFESSOR G. W. BISSELL seemed to think it not a fair statement that a student who enters a college and chooses one of the engineering courses, and who afterwards changes his course, loses four years' time. He had known instances in which a student entering in civil engineering had changed to electrical engineering after one year, without sacrificing very much of the first year's time or losing very much of the second year's time ; the student need not throw away the whole four years if he enters in the ordinary way and then finds that he has made a mistake and changes to some other course. Then as to the elective system, or the elective feature of the system discussed by Professor Wadsworth, if the student were to enter any engineering college and elect, for instance, hydraulic engineering, he would follow out much the same course of study under the elective system at the Michigan School of Mines as he would under a prescribed system in any other engineering college of high standing, provided, of course, that the professors in both schools have the same ideas—and there would not probably be much difference—as to what constitutes a proper course of study in hydraulic engineering. It seemed

to be not very different from specializing, or taking a special engineering course in other institutions of the same grade.

PROFESSOR ALBERT KINGSBURY said that he could hardly see how this elective system could apply in the average college. Indeed, his understanding was that Professor Wadsworth does not think it will so apply.

PROFESSOR WADSWORTH replied that his position was that, while the elective system can be used in every college, the special course that had been arranged for the Mining School would not, as it then stood, apply to the average college ; he would always vary it with the special conditions of every institution.

PROFESSOR KINGSBURY thought that he could hardly make a beginning with an elective system in a college such as the one in which he is occupied. The elective system which has been discussed appears to be one in which the student is lead to suppose that he is doing the electing, while in fact the faculty is doing it, and the chief gain comes from a mere matter of policy in working upon the human nature of the students.

PROFESSOR WADSWORTH replied by asking if it is not always well to oil the machinery, in order to make it run more smoothly and with less friction.

PROFESSOR KINGSBURY further explained as his understanding of the system that, if the student is to take applied mechanics, the professor says to him, " You must have the subject of calculus," and when he attempts to study the calculus he is told, " You must first know algebra," and when he wishes to study algebra the professor says to him, " It is necessary for you to know something about arithmetic," and so on

down; and when all of these are followed down in this inverse order and properly fixed, there is a fixed course of instruction; and when provision is made for giving the instruction in this course, there must be a fixed schedule; and by the time the fixed schedule is established, there is a fixed system just such as most colleges are following.

PROFESSOR WADSWORTH said that it seemed to him, from the discussion, that the trouble is that none of the gentlemen, or few of them at any rate, have ever used the elective system in engineering work, and consequently most of the criticisms do not apply to that system as it actually is. It should not be supposed that the speaker had no knowledge of a required system. In an experience of thirty-three years, during the chief portion of the time he had taught in a fixed system, and had used optional systems and required systems "ad infinitum" almost, so that with most of the purposes of the required systems he is familiar. From actual experience he would say that the amount of time, labor, drudgery and other things that the elective system does save, is something that he is unable to find words adequate to express, so that his hearers will understand it without trying it. This saving is an actual fact, speaking from experience, and an experience of long years with the different systems. In certain schools he would advise keeping the required system, and he certainly would be governed always by the practical requirements of each special case. He would not, in the case of another college, introduce any new system until he knew that a change would be proper and beneficial to the institution. Most of

the objections which had been here made, apply to an imaginary something, different from a true elective system. He would be glad to send to any one the catalogue of the Michigan Mining School, as it will show, as near as a catalogue can, how the elective system has been arranged there.

PROFESSOR Goss said that he should regret to have it inferred from his previous remarks that he questioned the value of the work done in the institution with which Professor Wadsworth is connected. He could readily believe that Professor Wadsworth's plan might give good results, and desired simply to question whether the reforms which are stated to be the result of an adoption of the elective system could not have been brought about in some other way. If so, he thought that the success of the reforms should not be used as an argument to sustain the elective system.

PROFESSOR W. K. HATT found that his impression was not clear relative to one thing. The author said that when the student found out the incompetence of the instructor he would leave him and go to another class. The speaker wished to inquire if the student was permitted to control the character of his instruction, and, if so, on what features the student based his judgment.

PROFESSOR WADSWORTH replied that he hardly intended to convey that idea. It was stated that the elective system would show up the incompetence of the instructor, because the teacher in Mining Engineering or in any advanced subject would require that the students should have had proper instruction in calculus, analytic mechanics, mechanism, etc. If stu-

dents came to that professor prepared properly, it would then be discovered that they were well taught; if improperly instructed, this would also be known as quickly; since, if any professor is to do his work rightly, the students must be thoroughly taught in the required preparatory subjects when they come to him. In other words, every professor naturally insists that the preparatory work for his classes shall be done as it should be, since stopping a student in one subject does not cost him a year's time, as it often does in the required systems. He must insist on this or it is fatal to his instruction. It is in part this necessary building up from the foundation in this way that makes the elective system's success. The students themselves are enthusiastic over their studies, and they do not wish to be under a teacher who does not do good work.

Further, it has resulted in a decided elevation of the moral tone. It has an excellent effect where there is an incompetent professor, or one who is exceedingly unpopular, or one who does not handle matters in the right manner. Instead of a class rebellion, or perhaps a petition presented to the faculty or board, accompanied with a statement that the students will leave the school, etc., the result is simply a resolve on the part of the students not to take the subjects that professor has the next year. It culminates not in a rebellion, but in the idea "I will not take that subject next year. I will go more into the civil engineering line, or the metallurgical line, or into some other subject that will enable me to avoid the obnoxious teacher." This attitude quickly shows itself and the trouble is readily diagnosed. The teacher is told by

a live president what the trouble is, and he is obliged to do his work properly or leave the institution.

PROFESSOR BULL inquired if those professors who offer "snaps," as they call them, become popular at once and attract the most students?

PROFESSOR WADSWORTH replied that they do not become popular in engineering colleges, but they do attract students to lectures in literary colleges, where there are usually numerous subjects that require no advanced preparation. The question of the literary education of a student is entirely different from the question of his professional education. The professional student in most cases knows that, unless his work is done well, he will not be a competent man in his profession after graduating. In the case of a literary college many of the students desire only athletics and to obtain a polish, consequently they elect anything that will give them their polish and degree. Further, in a literary college there is usually a much larger range of studies from which students can choose.

PROFESSOR M. T. MAGRUDER wished to ask Professor Wadsworth if his students are not very much older than the average student of the technical colleges?

PROFESSOR WADSWORTH said that the average age this year is 23 years; in former years it had sometimes been greater, sometimes less. Certain conditions in the Mining School may have raised it compared with most other colleges, notably the special students, since there have been some who were 56 years of age.

PROFESSOR KINGSBURY asked if he understood correctly that this system had been in use only one year at the Michigan Mining School?

PROFESSOR WADSWORTH replied that this was all.

PROFESSOR KINGSBURY said that he would be much pleased to hear at the next meeting how it works, and for several years following.

ENTRANCE REQUIREMENTS FOR ENGINEERING COLLEGES.

REPORT OF THE SPECIAL COMMITTEE.

To the Society for the Promotion of Engineering Education :

Your Committee on Entrance Requirements here-with presents the following report :

It has endeavored to fill the gaps existing at the time of the report made at the last meeting, and has succeeded in obtaining 98 responses to the questions of the college circular, out of the total number of 110 colleges that are included within this report. It has also received about 250 replies to the circular sent to preparatory schools. This has taken considerable persistent effort on the part of the committee, some of the reports having been received only within the last month. But it feels satisfied that such a mass of valuable matter and expression of authoritative opinion regarding the questions under investigation by the committee has not heretofore been gathered. The committee desires to express its appreciation of the way in which its correspondents have responded to its requests, notwithstanding the natural reluctance which many feel in expressing themselves, or the schools or colleges which they represent, on these important subjects.

The material thus gathered has been carefully analyzed and studied with the view of first ascertaining the facts in regard to existing conditions, and second, gaining as clear an insight as possible into the spirit

and trend of present movements, likely to affect the relations of secondary and higher technical education.

The work of the committee has been naturally divided along the line of the two circulars issued, and the results will be given under the same division. For the sake of easy reference, parts of these circulars, though appearing in our report of last year, are again inserted here.

A. REPLIES FROM COLLEGES.

The circular sent to colleges included the following questions:

1. *Present Entrance Requirements.* In addition to the catalogue, copies of examination papers actually used are desired, also a general statement as to the number of conditions allowed and regulations governing their removal.
2. *Changes of Requirements.* (a) What (educational) considerations guide the college in making or not making changes?
(b) In what direction and to what extent are changes desired or desirable?
3. *Uniformity of Requirements.* To what extent is it desirable and practicable that the requirements for admission to different engineering colleges be assimilated, *i. e.*, in the sense that requirements in a given subject should be identical in kind, but not necessarily in extent?
4. *Preparatory Schools.* What assistance, if any, can be rendered to preparatory schools by the engineering colleges—for example, by co-operative action?

5. *Admission by Certificate.* (a) To what extent does this replace examinations?

(b) What are the present rules for such admission, and what latitude is allowed in their execution? (Detailed information is desired.)

(c) Is the operation of the system satisfactory?

(d) Is it susceptible of further extension, for example, by inter-collegiate action?

CLASSIFICATION OF COLLEGES.

For the purpose of exhibiting the facts in regard to requirements, several classifications have been tried. The geographical basis used last year brought out certain facts, but its usefulness seemed exhausted. The one finally used is believed to be best adapted to the purpose. It is a very difficult matter to distribute the different colleges among the various classes on any other basis than the geographical one, and it has been necessary to exercise some judgment in determining the class of particular institutions. The classification adopted is *not* to be taken as showing the relative general merits or standing of the colleges; it relates solely to the matter of entrance requirements. The basis of the classification is as follows, viz.:

CLASS A. Those colleges whose requirements for admission include at least Algebra through Quadratics, Plane Geometry, Solid Geometry or Plane Trigonometry, one year of Foreign Language, and moderately high requirements in English. 31 colleges.

CLASS B. Those colleges of the remaining list whose

requirements include Algebra through Quadratics and Plane Geometry. 33 colleges.

CLASS C. Those colleges whose requirements in mathematics are *lower* than Algebra through Quadratics and Plane Geometry. 25 colleges.

CLASS D. Those colleges that offer no courses in engineering as such, but do work analogous to that of an engineering college, generally under the head of mechanic arts. These colleges do not appear to any great extent in the tables that relate to the present facts. They are included in other tabulations in order to show their tendencies, as many of them will undoubtedly develop into genuine engineering colleges. A few of them now give engineering work in a fifth or post-graduate year. 18 colleges.

CLASS E. Those colleges that have no entrance requirements as such, though doing engineering work of good grade. The system of education followed is so different from that of other institutions that they do not fit into this comparison. They do not appear to any great extent in the tabulations. 3 colleges.

COLLEGES—CLASS A.

Those with average high requirements that include Algebra through Quadratics, Plane Geometry, Solid Geometry or Plane Trigonometry, substantial English requirements and at least one year of Foreign Language Work—31 colleges.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Canada, Montreal.....	McGill University.....	'95-6	H. T. Bovey.....	Dean Faculty App. Sec.
California, Palo Alto.....	Leland Stanford Jr. University*	'94-5	{ Charles D. Marx.....	Prof. Civ. Eng.
California, Berkeley.....	University of California.....	'94-5	{ O. L. Elliott.....	Registrar.
Colorado, Boulder.....	University of Colorado.....	'94-5	{ S. B. Christy.....	Prof. Mining.
Connecticut, New Haven.....	Sheffield Scientific School.....	'95-6	{ James Sutton.....	Recorder of Faculty.
Iowa, Iowa City.....	University of Iowa.....	'94-5	Henry Fulton.....	Prof. Civ. Eng.
Iowa, Mount Vernon.....	Cornell College.....	'94-5	A. J. Dubois.....	Prof. Civ. Eng.
Illinois, Chicago.....	Armour Institute.....	'94-5	S. N. Williams.....	Prof. Civ. Eng.
Illinois, Champaign.....	University of Illinois.....	'94-5	T. C. Roney.....	Dean of Faculty.
Kansas, Lawrence.....	University of Kansas.....	'96	Ira O. Baker.....	Prof. Civ. Eng.
Massachusetts, Boston.....	Mass. Institute of Technology.....	'95	F. O. Marvin.....	Dean School of Eng.
Massachusetts, Cambridge.....	Lawrence Scientific School.....	'95	Geo. F. Swain.....	Prof. Civ. Eng.
Massachusetts, College Hill.....	Tufts College.....	'94-5	Ira N. Hollis.....	Prof. Civ. Eng.
Massachusetts, Worcester.....	Worcester Polytechnic Inst.....	'96	F. T. Daniels.....	Secy. Eng. Faculty.
Michigan, Ann Arbor.....	University of Michigan.....	'94-5	T. C. Mendenhall.....	President.
Minnesota, Minneapolis.....	University of Minnesota.....	'94-5	Charles E. Greene.....	Prof. Civ. Eng.
Missouri, St. Louis.....	Washington University.....	'96	Cyrus Northrup.....	President.
Montana, Deer Lodge.....	Montana School of Mines.....	'98-4	W. S. Chaplin.....	Chancellor.
Nebraska, Lincoln.....	University of Nebraska.....	'96	O. V. P. Slout.....	Assoc. Prof. Civ. Eng.
New Hampshire, Hanover.....	Thayer School Civil Engt.....	'96	Robert Fletcher.....	Director.

* Elective system of admission—English the only fixed requirement.

† No language, essentially a post-graduate school.

COLLEGES—CLASS A CONTINUED.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
New Jersey, Hoboken	Stevens Institute	'94-5	A. Reisenberger	Secretary.
New Jersey, Princeton	J. C. Green School of Science	'94-5	H. S. S. Smith	Ast. Prof. Civ. Eng.
New York, Ithaca	Cornell University	'94-5	Geo. P. Bristol	Registrar.
New York, Schenectady	Union University	'94-5	Olin H. Landreth	Prof. of Eng.
			P. R. Hutton	
			J. H. Van Amringe	
			P. B. Crooker	
			R. S. Woodward	
			W. H. Burr	
			Carly Staley	
New York, New York	Columbia University	'94-5	Ward Baldwin	President.
Ohio, Cleveland	Case School App. Science	'94-5	H. W. Spangler	Prof. Civ. Eng.
Ohio, Cincinnati	University of Cincinnati	'94-5	Edgar Marburg	Prof. Mech. Eng.
Pennsylvania, Philadelphia	University of Pennsylvania	'94-5	Isaac Sharpless	Prof. Civ. Eng.
Pennsylvania, Haverford	Haverford College	'94-5	W. T. Duton	President.
Pennsylvania, Meadville	Allegheny College	'94-5	Storm Bull	Prof. Civ. Eng.
Wisconsin, Madison	University of Wisconsin	'95-6		Prof. Steam Eng.

COLLEGES—CLASS B.

Those with Requirements that include Algebra through Quadratics and Plane Geometry. 88 colleges.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Canada, Toronto.....	School of Practical Science.....	'95-'6	John Galbraith.....	Director.
Canada, Fredericton.....	University of New Brunswick.....	'95	S. M. Dixon.....	Prof. Civ. Eng.
Delaware, Newark.....	Delaware College.....	'95	F. H. Robinson.....	Prof. Civ. Eng.
Iowa, Cedar Rapids.....	Coe College.....	'94-'5		
Iowa, Des Moines	Drake University.....	'95-'6	J. E. Ostrand.....	Secretary of Faculty.
Idaho, Moscow.....	University of Idaho.....	'94-'5	C. Leo Mees.....	President.
Indiana, Terre Haute.....	Rose Polytechnic Institute.....	'95	A. Morrissey	President.
Indiana, Notre Dame.....	Notre Dame University.....	'94-'5	{ M. J. Mcue	Prof. Civ. Eng.
Indiana, Richmond	Earlham College.....	'94-'5	R. L. Sackett	Prof. App. Math.
Louisiana, New Orleans.....	Tulane University.....	'94-'5	John M. Ordway	
Maine, Orono.....	Maine State College.....	'94-'5	{ A. W. Harris	President.
Michigan, Houghton	Michigan Mining School.....	'95	G. H. Hamlin	Prof. Civ. Eng.
Missouri, Columbia.....	University of Missouri.....	'94-'5	M. E. Wadsworth	Director.
Nevada, Reno.....	University of Nevada.....	'94-'5	Wm. Shrader	Prof. Elect. Eng.
New Jersey, New Brunswick.....	Rutgers College.....	'94-'5	Joseph E. Stubbs	President.
New Mexico, Socorro.....	School of Mines.....	'95-'6	Edward A. Bowser	Prof. Math. and Eng.
New York, Troy.....	Rensselaer Polytechnic Inst.....	'95	W. H. Seaman	Director.
New York, New York.....	New York University.....	'94-'5	P. C. Ricketts	
New York, Brooklyn.....	Brooklyn Polytechnic Institute.....	'94-'5	Charles H. Show	V. Dean Eng. School.
New York, Syracuse*	Syracuse University*.....	'94-'5	G. W. Plympton	Prof. Phys. Sci. and Eng.
Ohio, Columbus	Ohio University.....	'93-'4	John R. French	Vice Chancellor.
Pennsylvania, S. Bethlehem	Lehigh University	'94-'5	W. H. Scott	President.
				Secretary of Faculty.

* Course in architecture only.

COLLEGES—CLASS B CONTINUED.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Pennsylvania, Swarthmore	Swarthmore College	94-5	Arthur Beardsey	Prof. Eng.
Pennsylvania, Easton	Lafayette College	94-5	E. D. Warfield	President.
Pennsylvania, State College	Pa. State College	94-5	G. W. Atherton	President.
Rhode Island, Providence	Brown University	94-5	Ollis E. Randall	Asso. Prof. Mech. Draw.
South Dakota, Rapid City	School of Mines	95-6	F. C. Smith	Vice-President.
Tennessee, Nashville	Vanderbilt University	94-5	J. H. Kirkland	Chancellor.
Texas, Austin	University of Texas	94-5	T. U. Taylor	Prof. Civ. Eng.
Utah, Salt Lake City	University of Utah	95-6	{ J. E. Talmage	President.
Vermont, Burlington	University of Vermont	98-4	{ J. T. Kingsbury	Prin. Mining School.
Washington, Pullman	Washington Agricul. College	94-5	M. H. Buckham	President.
West Virginia, Morgantown	West Virginia University	94-5	{ A. R. Saunders	Prof. Mech. Eng.
			{ P. B. Reynolds	Acting President.
			{ W. S. Aldrich	Prof. Mech. Eng.

COLLEGES—CLASS C.

Those having Requirements in Mathematics below Algebra through Quadratics and Plane Geometry. 26 Colleges.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Alabama, Auburn.....	Alabama Polytechnic.....	'95	John J. Wilmore	Prof. Mech. Eng.
Arizona, Tucson.....	University of Arizona	'98-4		
Arkansas, Fayetteville.....	Ark. Industrial University	'94	C. V. Kerr.....	Prof. Mech. Eng.
California, Pasadena.....	Throop Polytechnic.....	'95-6		
Colorado, Fort Collins.....	Colorado Agricul. College	'94-5	L. G. Carpenter.....	Prof. Eng.
Colorado, Golden.....	School of Mines.....	'94-5	Regis Chauvenet.....	President.
Georgia, Athens.....	University of Georgia.....	'94-5	C. M. Strahan.....	Prof. Civ. Eng.
Indiana, Lafayette.....	Purdue University.....	'94-5	James H. Smart.....	President.
Iowa, Ames.....	Iowa Agricul. College.....	'94-5	G. W. Bissell.....	Prof. Mech. Eng.
Kentucky, Lexington.....	Kentucky State College	'94-5	F. Paul Anderson.....	Prof. Mech. Eng.
Maryland, Annapolis.....	St. Johns College	'95	Thomas Fell.....	President.
Michigan, Ag. Coll. P. O.....	Michigan Agricul. College	'94-5	Lewis G. Gordon.....	President.
Missouri, Rolla.....	School of Mines.....	'95-6	W. B. Richards.....	Director.
New Hampshire, Durham.....	New Hampshire Ag. College	'95-6	C. S. Murkland.....	President.
New Mexico, Mesilla Park.....	New Mexico Agricul. College.....	'95	S. P. McCrea.....	President.
Pennsylvania, Chester.....	Penn. Military College	'95		
Pennsylvania, Allegheny.....	Western University of Pa.	'94-5	W. J. Holland.....	Chancellor.
Tennessee, Lebanon.....	Cumberland University	'95	A. H. Buchanan	Prof. Math. & Civ. Eng.
Tennessee, Knoxville.....	University of Tennessee	'94-5	{ T. W. Jordan	Dean.
Tennessee, Sevierville.....	University of the South	'94-5	{ W. W. Carson	Prof. Civ. Eng.
Texas, College Station.....	Texas Ag. and Mech. College	'94-5	S. M. Barton.....	Prof. Math.
Utah, Logan.....	Utah Agricul. College	'94-5	F. E. Geisecke.....	Prof. Drawing.
Vermont, Northfield.....	Norwich University	'96	James Johnson	Prof. Phys. & Mech. Eng.
Virginia, Blacksburg.....	Virginia Agricul. College	'94-5	John B. Johnson	Prof. Civ. Eng.
Wyoming, Laramie.....	University of Wyoming	'94-5	L. S. Randolph	Prof. Mech. Eng.
				Prof. Math.

COLLEGES—CLASS D.

Those giving Courses analogous to Engineering—generally with low Requirements or none at all. Not included in all of the following tabulations—18 colleges.

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Florida, Lake City.....	Florida Agricult. College.....	'94-5	H. C. Powers.....	Prof. Mech. Arts.
Georgia, Atlanta.....	Clarke University.....	'94-5	Lyman Hall	Chairman of Faculty.
Georgia, Atlanta.....	Georgia School of Technology	'94-5		
Iowa, Des Moines.....	Highland Park Normal Univ.....	'94-5	O. P. Hood.....	Prof. Mech. Eng.
Kansas, Manhattan.....	Kansas Agricult. College.....	'95-6		
Louisiana, Baton Rouge.....	Louisiana State University.....	'94-5	H. A. Hill.....	President.
Louisiana, New Orleans.....	Southern University.....	'93-4	R. W. Silverster.....	President.
Maryland, College Park.....	Maryland Agricult. College.....	'94	S. D. Lee.....	President.
Mississippi, A. & P. O.....	Mississippi Agricult. College	'95	James Reid	President.
Montana, Bozeman.....	Montana Agricult. College.....	'94-5		
North Carolina, Raleigh.....	North Carolina Agricult. College.....	'94-5	E. S. Keene.....	Prof. Mech.
North Dakota, Fargo.....	North Dakota Agricult. College.....	'94-5		
Oregon, Corvallis.....	Oregon Agricult. College	'94-5	Warren S. Locke.....	Head Master.
Rhode Island, Providence.....	R. I. School of Design.....	'94	J. H. Washburn.....	President.
Rhode Island, Kingston.....	Rhode Island Agricult. College	'95	R. G. Thomas.....	Prof. Math. and Eng.
South Carolina, Charleston.....	South Carolina Military Institute.....	'95	Lewis McLouth	President.
South Dakota, Brookings.....	South Dakota Agricult. College	'94-5	Scott Shipp	Superintendent.
Virginia, Lexington	Virginia Military Institute.....	'94-5		

COLLEGES—CLASS E.

**These do not appear in the following tabulations to any extent—3 colleges.*

LOCATION.	COLLEGE.	CATALOG. YEAR.	PERSONS REPLYING TO THE CIRCULAR.	POSITION.
Dist. of Columbia, Washington, Virginia, Charlottesville.....	Columbian University.....	'94-5	Charles E. Monroe.....	Dean School of Science.
Virginia, Lexington	University of Virginia.....	'94-5	W. M. Thornton.....	Chairman of Faculty.
	Washington and Lee University.....	'94-5	D. C. Humphreys.....	Prof. App. Math.

The system of education in use at these colleges of Class E, is such that they can not enter into this comparison. No requirements are published and the colleges as such have none. The fitness of an applicant for admission is determined by each department into which he desires to go. Professor Humphreys expresses dissatisfaction with present methods and says: "We are about to make a change, doing away with the preparatory classes and putting ourselves in line with the Middle States."

Professor Thornton says: "The law of the visitors imposes upon each professor the duty of ascertaining whether applicants for admission to his school are prepared or not to enter, and of classifying them after they have entered, but lays most stress on the graduating examinations at the end of the course. These are severe and a most satisfactory sieve. In one sense we have no entrance examinations whatsoever, while in another they are pretty strict, since each professor feels personally responsible if an ill-prepared man is admitted to his classes and has to shoulder any reproach that may be attached to it. For the Engineering Department the only admission test is in pure mathematics. We require a good practical acquaintance with Algebra, Plane and Solid Geometry, and Plane Trigonometry."

Dean Munroe says: "No entrance examinations are required. The policy is easy admission, but difficult graduation. Ninety per cent. at least of our students are mature persons, who have earned the money they pay their tuition with, and they, being thoroughly in earnest, are given every opportunity.

We expect students entering the first year to be prepared in English Grammar, Rhetoric, French Grammar, American History, Algebra through Quadratics, Plane Geometry, Elementary Physics and Chemistry, and the elements of Freehand and Mechanical Drawing."

The material gathered from the colleges is of two kinds, first, that relating to the facts as they now are, and second, that giving expressions of opinion concerning these, or proposed changes in requirements and methods of admitting students. The analysis will be given in this order, with some comments thereon.

THE PRESENT PRACTICE AS TO REQUIREMENTS.

1. *Existing Requirements.* The requirements for admission in the 89 colleges of classes A, B and C have been tabulated in detail (in Table I.) with the purpose of showing the great range and variety. The same material has been somewhat condensed and shown in different form in Table II. In Table III. are given what might be called average requirements, showing the points of common agreement between the colleges of each class. The data for these three tables have been taken almost entirely from the catalogues of 1895, supplemented by information gained through the circul-lars and by correspondence.

TABLE I.

SHOWING SUBJECTS REQUIRED FOR ADMISSION BY 89 COLLEGES
GIVING ENGINEERING COURSES AND THE NUMBER OF COL-
LEGES REQUIRING EACH.

From catalogues and replies to circulars.

SUBJECT.	CLASS A 31 COLLEGES.		CLASS B 33 COLLEGES.		CLASS C 25 COLLEGES.		TOTALS 89 COLLEGES.	
	Required.	Not required.	Required.	Not required.	Required.	Not required.	Required.	Not required.
Evidence of Morals...	12	19	12	21	10	15	34	55
Age 14 .....	..	12	..	..	..	..	2	40
" 15	2	..	3	19	9	..	14	..
" 16	14	..	8	..	6	..	28	..
" 17	2	..	1	..	1	..	4	..
" 18	1	..	..	..	..	..	1	..
Writing .....	..	31	1	32	4	21	..	..
Reading .....	..	31	3	30	5	20	5	81
Spelling	1	30	4	29	10	15	15	74
Geography	8	23	22	11	1	18	48	41
Arithmetic: To per-								
centage .....	..	10	..	6	2	2	2	18
Complete	21	..	27	..	21	..	69	..
Algebra: Elements,...								
Through Quadratics	18	..	21	..	20	3	20	3
Advanced	10	..	2	11	2	..	1	21
Complete	3	..	2	1	..	..	4	..
Geometry; Less than								
five Books.....	..	..	3	..	4	16	..	16
Plane or more.....	5	..	20	..	5	..	30	..
Complete	26	..	2	10	1	..	1	36
Trigonometry: Plane,..	9	20	3	2	31	1	11	76
Complete	2	..	1	..	..	..	2	..
Mensuration	1	..	..	1	..	..	2	..
Elementary Mechanics	1	..	..	1	..	..	2	..
Higher Mathematics..	1	..	..	..	..	..	1	..
Drawing	6	25	3	5	28	1	11	78
Manual Training or								
Practice	1	..	1	..	..	..	2	..
History: U. S.....	24	7	4	23	10	16	1	63
Local.....	1	..	..	2	..	1	..	4
English	4	..	4	2	1	1	..	7
General	5	..	2	7	3	3	15	..
Greek and Roman..	4	17	5	3	..	21	1	56
Ancient .....	..	..	1	1	..	..	2	..
Modern	1	..	1	1	..	..	1	2
Civil Government.....	4	..	1	3	..	1	7	2

TABLE I.—CONTINUED.

SUBJECT.	CLASS A 81 COLLEGES.			CLASS B 38 COLLEGES.			CLASS C 26 COLLEGES.			TOTALS 89 COLLEGES.		
	Required.	Not required.	Elective.	Required.	Not required.	Elective.	Required.	Not required.	Elective.	Required.	Not required.	Elective.
Local Government.	1	...	...	...	...	...	...	...	...	1	...	...
General : Bookkeeping.....	1	...	...	2	...	1	...	...	...	3	...	1
Elocution.....	...	...	...	1	...	1	...	...	...	...	...	1
Mental Science .....	...	...	...	1	...	1	...	...	...	...	...	2
Logic.....	...	...	...	...	...	...	...	...	...	1	...	...
Economics.....	1	...	...	1	...	1	...	...	...	1	...	1
Theory of Teaching	...	...	...	...	...	...	...	...	...	...	...	2
Miln's "Realm of Nature"	1	...	...	...	...	...	...	...	...	1	...	...
Science : Physics	19	12	5	14	19	2	3	22	2	36	53	9
Phys. Lab.....	3	...	3	...	...	1	...	...	...	3	...	4
Chemistry	10	21	7	4	29	3	...	25	1	14	75	11
Chem. Lab.....	1	...	2	...	...	1	...	...	...	1	...	3
Physical Geography	11	20	3	8	25	4	8	17	1	27	62	8
Physiology	8	23	5	6	27	3	7	18	1	21	68	9
Botany	5	26	7	6	27	4	...	25	1	11	78	12
Zoölogy	1	...	5	...	...	2	...	...	1	1	...	8
Astronomy	1	...	4	1	...	2	...	...	...	2	...	6
Geology.....	2	...	2	...	...	...	...	...	...	2	...	2
Mineralogy.....	...	...	2	...	...	...	...	...	...	...	...	2
Meteorology	1	...	...	...	...	...	...	...	...	1	...	...
Natural History.....	...	...	...	1	...	...	...	...	...	1	...	...
Biology .....	...	...	1	...	...	...	...	...	...	...	...	1
Introduction to Science	1	...	...	...	...	...	...	...	...	1	...	...
English (Grammar, Anal., Bad Eng.)....	18	13	...	25	8	...	22	3	...	65	24	...
Composition	3	...	...	10	...	...	11	...	5	24	65	...
Rhetoric	8	...	1	11	...	...	...	...	...	24	65	1
English Literature..	6	...	2	4	...	1	...	1	10	79	4	...
Classics, less than 5	1	{}	6	6	...	2	3	19	...	9	...	...
5 to 10.....	8		5	16	...	3	16	...	16	...	41	...
10 or more.....	16	...	6	...	...	1	1	19	...	23	...	...
Essay : no limit.....	17	9	...	15	14	...	3	18	...	35	...	...
100 to 400 words	2	...	...	1	...	...	4	...	...	7	41	...
more than 400.....	3	...	...	3	...	...	...	...	...	6	...	...
Three Years.....	1	...	...	...	...	...	...	...	...	1	...	...
Etymology.....	...	...	...	2	...	...	...	...	...	2	...	...
Latin Elements.....	1	...	...	...	...	...	...	...	...	1	...	...
N. E. Requirements or nearly.....	14	...	...	5	...	...	...	...	...	19	...	...

TABLE I. (CONTINUED).

SUBJECT	CLASS A 31 COLLEGES.			CLASS B 28 COLLEGES.			CLASS C 25 COLLEGES.			TOTALS 89 COLLEGES.		
	Required.	Not required.	Elective.	Required.	Not required.	Elective.	Required.	Not required.	Elective.	Required.	Not required.	Elective.
Foreign Languages.....	...	2	...	16	...	...	26	...	...	44	...	...
Spanish, 1 yr.....	...	1	...	...	...	...	...	...	...	1	...	1
Spanish, 2 yrs.....	...	1	...	...	...	...	...	...	...	2	...	2
Greek.....	1	...	...	...	...	...	...	...	1	...	...	...
Latin.....	7	...	...	...	...	...	...	...	1	...	...	...
Latin, 2 yrs.....	2	...	...	2	...	...	...	...	...	2	...	...
French, 1 yr.....	2	...	1	...	...	...	...	...	1	3	...	3
French, 2 yrs.....	1	...	1	...	1	...	...	...	2	...	...	3
German.....	...	1	...	...	1	...	...	1	...	...	...	3
Fr. 1 yr., or Ger. 1 yr.....	4	...	1	...	...	...	...	...	...	5	...	...
Fr. 1 yr., and Ger. 1 yr.....	...	2	...	...	...	...	...	...	...	2	...	...
Fr. 2 yrs., or Ger. 2 yrs.....	9	...	2	...	...	...	...	...	...	11	...	...
Fr. 2 yrs., and Ger. 2 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 1 yr., or Ger. 1 yr., or Lat. 1	1	...	3	...	...	1	...	...	...	5	...	...
Fr. 2 yrs., or Ger. 2 yrs., or Lat. 2	1	...	...	...	...	...	...	...	1	...	...	...
Fr. 1 yr., and Ger. 1 yr., and add. Lang. 1 yr.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 1 yr. and Ger. 1 yr. and Lat. 2	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 2 yrs., and Ger. 1 yr., and Lat. 3 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 1 yr., and Ger. and Sci. 1 yr., or Lat. 3 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. or Ger. or Lat. 3 yrs., any combination.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 1 yr., or Ger. 1 yr., and Lat. 2 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 2 yrs., or Ger. 2 yrs., and Lat. 2 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 1 yr., or Ger. 1 yr. or add. Math. 1 yr.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 2 yrs., or Ger. 2 yrs., or Lat. 2 yrs., or Eng. 2 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Fr. 2 yrs., or Ger. 2 yrs., or Lat. 3 yrs., or Greek 2 yrs.....	1	...	...	...	...	...	...	...	...	1	...	...
Ger. 3 yrs., or Lat. 3 yrs.....	...	...	1	...	...	...	...	...	...	1	...	...
Ger. 1 yr., and Ger. 2 yrs., or Lat. 2 yrs., (any comb.)....	1	...	...	1	...	...	...	...	...	1	...	...
Lat. 3 yrs., and Greek 1 yr., Lat., Fr., Ger., Grk., 2 yrs., any combination.....	1	...	...	1	...	...	...	...	...	1	...	...

TABLE II.
SHOWING ENTRANCE REQUIREMENTS IN CONDENSED FORM.

SUBJECTS.	CLASS A 31 COLLEGES.			CLASS B 33 COLLEGES.			CLASS C 25 COLLEGES.			TOTALS. 89 COLLEGES.		
	Required.	Not Required.	Elective.									
Morals, Evidence of.....	12	19	...	12	21	...	10	15	...	34	55	...
Age Qualification.....	19	12	...	14	19	...	16	9	...	49	40	...
Writing.....	...	31	...	1	32	...	4	21	...	5	84	...
Reading.....	...	31	...	3	30	...	5	20	...	8	81	...
Spelling.....	1	30	...	4	29	...	10	15	...	15	74	...
Geography.....	8	23	...	22	11	1	18	7	1	48	41	2
Mathematics: Arithmetic only	...	...	...	...	...	3	...	...	3	...	...	...
Elem. Alg., no Geom.....	...	...	...	...	...	13	...	...	13	...	...	...
Elem. Alg., Geom. Plane....	1	...	...	22	...	9	...	...	32	...	...	...
Alg., Plane and Solid Geom.	18	...	...	10	...	1	...	...	28	...	1	...
Alg., Geom., and Trig. Plane.	9	...	2	1	...	1	...	...	10	...	3	...
Al., Geom., and Pl. and Sph.	...	...	...	...	...	...	...	...	...	...	...	...
Trig.....	2	...	1	...	...	...	...	...	2	...	1	...
Higher Mathematics.....	1	...	...	...	...	...	...	...	1	...	...	...
Drawing.....	6	25	3	5	28	1	...	25	...	11	78	4
Manual Training.....	1	...	...	1	...	...	...	...	2	...	...	...
History: 1 subject.....	14	4	4	17	5	2	14	7	1	45	16	7
2 "	...	...	3	9	...	1	4	...	1	24	...	5
3 "	...	...	2	...	1	2	...	...	4	...	1	...
Civil Government.....	4	...	1	3	...	1	...	...	7	...	2	...
Science: 1 subject.....	1	8	2	7	14	1	7	13	...	15	35	3
2 "	...	...	9	...	3	...	4	...	1	16	...	1
3 "	...	...	7	...	3	8	...	1	...	16	...	3
4 "	...	...	4	...	2	...	4	...	...	4	...	6
5 "	...	...	1	...	2	...	...	...	1	1	...	3
6 "	...	...	...	...	...	...	1	...	...	...	1	...
8 "	...	...	1	...	...	...	...	...	1	...	...	...
1 yr's. work.....	...	...	...	...	1	...	...	...	1	...	...	...
English: Grammar only.....	*1	...	...	3	*1	...	7	...	...	11	1	...
" and Comp.....	2	...	...	7	...	...	10	...	...	19	...	...
Advanced.....	14	...	...	18	...	...	7	...	...	39	...	...
N. E. Requirements or nearly.....	14	...	...	...	...	...	...	...	...	...	...	...
Foreign Language: 1 year.....	14	...	...	5	...	...	...	...	...	19	...	...
2 years.....	8	12	...	4	19	...	1	24	...	13	45	...
3 "	...	...	8	...	...	...	...	...	...	24	...	...
4 "	...	...	3	...	1	...	...	...	...	4	...	...
6 (?) ".....	1	...	...	1	...	...	...	...	2	...	...	...
Fr., Ger., Lat. or Greek.....	...	...	...	...	...	1	...	...	...	...	1	...
Fr., Ger., Lat., Gr. or Span- ish.....	...	...	1	...	...	...	...	...	...	...	3	...
English failure a bar.....	2	...	...	1	...	...	...	...	...	3	...	...
Mathematics failure a bar.....	2	...	...	1	...	...	...	...	...	3	...	...

* Thayer. † Mich. Mining School. ‡ Thayer and Leland Stanford, Jr.

TABLE III.

AVERAGE OF COMPOSITE REQUIREMENTS.

The subjects below are required by 100 per cent. of the colleges. These are minimum requirements.

CLASS A 81 COLLEGES.	CLASS B 88 COLLEGES.	CLASS C 25 COLLEGES.
Algebra through Quadratics. Plane Geometry. Solid Geometry or Plane Trigonometry. Some Advanced English (except 1 college). One year Foreign Language(except 2 colleges)	Elementary Algebra. Part of Plane Geometry. Some Advanced English (except 1 college).	Arithmetic (except 1 college). Elementary Algebra (except 8 colleges). Elementary English.

Each of the subjects below is required by 75 per cent. of the colleges.

Algebra through Quadratics. Plane and Solid Geometry. United States History. 1 Subject in Science. Advanced English with some Classics. At least 1 year Foreign Language.	Arithmetic. Algebra through Quadratics. Plane Geometry. 1 Subject in History. English Grammar. Some Advanced English.	Geography. Arithmetic. Elementary Algebra. English Grammar.
--	--	--

Each of the subjects below is required by 50 per cent. of the colleges.

An age qualification. Arithmetic. Algebra through Quadratics. Plane and Solid Geometry. United States History. Some Additional History. Physics. A Second Science. English Grammar. 10 or more Classics. Essay. N. E. Requirements (18 colleges). 2 years Foreign Language.	Geography. Arithmetic. Algebra through Quadratics. Plane Geometry. United States History. 1 Subject in Science. English Grammar. About 5 Classics. Essay.	Age Qualification. Geography. Arithmetic. Elementary Algebra. United States History. English Grammar.
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TABLE III. (CONTINUED).

Each of the subjects below is required by 25 per cent. of the colleges.

CLASS A 81 COLLEGES.	CLASS B 88 COLLEGES.	CLASS C 25 COLLEGES.
Evidence of Morals.	Evidence of Morals.	Evidence of Morals.
Age Qualification.	Age Qualification.	Age Qualification.
Geography.	Geography.	Spelling.
Arithmetic.	Arithmetic.	Geography.
Advanced Algebra.	Advanced Algebra.	Arithmetic.
Plane and Solid Geometry.	Plane and Solid Geometry.	Elementary Algebra.
Plane Trigonometry.	United States History.	Plane Geometry.
United States History.	Some Additional History.	United States History.
Some Additional History.	Physics.	Physical Geography.
Physics.	Physical Geography.	Physiology.
Chemistry.	English Grammar.	English Grammar.
Physical Geography.	Composition.	Composition.
Physiology.	Rhetoric.	
English Grammar.	5 to 10 Classics.	
Rhetoric.	Essay.	
10 or more Classics.	2 years Foreign Language	
Essay.		
N. E. Requirements.		
2 years Foreign Language.		

From the preceding table (No. III.), tabulating the differences between classes on the basis of two terms to a school year and using as a unit of measure one study for one term, the following results appear:

	100 % Basis.	75 % Basis.	50 % Basis.	25 % Basis.
Differences between Classes A and B...				
" " " B " C..."	5 2	5 4	7 4	6 10

Or, expressing this in another way, there is a difference of something less than one year's work between

Classes A and B, and about one-half year's work between Classes B and C.

2. *Examination Papers.*—Because of the limited number of sets of papers sent in, as well as lack of time, no very thorough study of examination questions has been made. They have been examined, however, and compared with catalogue requirements. In the great majority of cases the questions set are up to the nominal requirements and adapted to determine the nature of the candidate's preparation. The following colleges have sent in sample sets of questions :

CLASS A.	CLASS B.	CLASS C.	CLASS D
Armour California Case Columbia Cornell Illinois Kansas Lawrence (Harvard) Massachusetts Institute McGill Pennsylvania Princeton Sheffield (Yale) Stanford Stevens Tufts Union Wisconsin	Brown..... Brooklyn Polytechnic..... Delaware..... Lehigh..... Michigan Mining..... New York..... Rose..... Rutgers..... Vanderbilt	Colorado School Mines..... Colorado Agricultural..... Iowa Agricultural..... New Hampshire Agricultural..... Tennessee..... Texas Agricultural.....	Georgia School of Technology..... Kansas Agricultural..... Mississippi Agricultural.....

Total, 36 colleges.

1. No certificates taken.
2. Accept certificates to a small or moderate extent.
3. Accept certificates to some undefined extent.
4. Accept certificates to a large extent.

3. *Entrance Conditions.*—The practice as to conditions and their removal is shown in the following table :

TABLE IV.
ENTRANCE CONDITIONS.
Abstract of Replies to College Circulars.

	A COLLEGES. 29 REPLIES.	B COLLEGES. 28 REPLIES.	C COLLEGES. 25 REPLIES.	D COLLEGES. 18 REPLIES.	E COLLEGES. 167 REPLIES.
No Regulations (so reporting).....	2	2	1	...	5
Number of Conditions. No answer.....	5	10	11	17	43
None allowed.....	1	1	2	...	4
One ".....	2	3	5	2	12
Two ".....	5	3	2	...	10
Three ".....	6	3	...	...	9
Variable to suit each case.....	4	4	...	...	8
Some indefinite number.....	5	7	5	1	18
Allowed in Modern Language.....	2	1	...	...	3
6 periods of work per week.....	...	1	...	...	1
Removal of Conditions. No Answer.....	15	11	17	17	60
Within 8 months.....	2	3	...	...	5
" $\frac{1}{2}$ year.....	3	4	2	1	10
" 1 year.....	7	6	2	2	17
" 2 years.....	1	...	...	...	1
As soon as possible.....	...	1	...	...	1
By good class standing.....	...	...	1	...	1
Before advance work is taken.....	...	1	...	...	1
By examination at fixed time.....	...	...	1	...	1
By examination when reported by tutor as ready.....	1	...	...	...	1
By class work in prep. dept.....	4	6	1	...	11
All conditions to be removed before matriculation or full standing.....	3	2	...	...	5
*No Failure in Mathematics allowed.....	3	3	...	...	6
* " " " English ".....	2	2	1	...	5
* " " " Physics ".....	1	...	...	...	1

* It is not clear that this prevents admission in all of these cases.

4. *Admission by Certificate.*—The following grouping of colleges is used, based on the extent of their practice. Those marked thus (*) seem to have fair regulations governing admission by certificate.

(a) THOSE NOT ACCEPTING CERTIFICATES.

Class A.	Class B.	Class C.	Class D.
Lawrence (Harvard). Mass. Institute. Princeton. Sheffield (Yale). Stevens. Thayer (Dartmouth).	Brooklyn Polytechnic. Notre Dame.	Texas Agricultural. Virginia Agricultural.	S. C. Military Institute. Georgia School Technology.
6 colleges.	2 colleges.	Total, 12 colleges.	2 colleges.

(b) THOSE ACCEPTING CERTIFICATES TO A SMALL OR MODERATE EXTENT.

Class A.	Class B.	Class C.	Class D.
Columbia.* Tufts.* Worcester Polytechnic.	Delaware. Lehigh. Rensselaer. Rose. Vanderbilt.*	Alabama Polytechnic. Georgia.	N. Dakota Agricultural. S. Dakota Agricultural.
8 colleges.	6 colleges.	Total, 12 colleges.	2 colleges.

(c) THOSE ACCEPTING CERTIFICATES TO SOME UNDEFINED EXTENT.

CLASS A.	CLASS B.	CLASS C.	CLASS D.
Armour. Case. Cincinnati. Cornell.* Union.	Idaho.* Nevada. New Brunswick. New Mexico School of Mines. New York.* Rutgers. Utah. Vermont.* Washington Agricultural. West Virginia Univ.*	Colorado School of Mines. Colorado Agricultural. Kentucky. Michigan Agricultural. New Mexico Agricultural. St. John's. University of the South. Western Pennsylvania.	Mississippi Agricultural. Rhode Island Agricultural.

6 colleges.

10 colleges.

Total. 25 colleges.

8 colleges.

2 colleges.

(d) THOSE ACCEPTING CERTIFICATES TO A LARGE EXTENT.

CLASS A.	CLASS B.	CLASS C.	CLASS D.
Allegheny.	Brown. Farham.	Arkansas Industrial.	Kansas Agricultural.
California.*	Colorado.	Iowa Agricultural. Missouri School of Mines.	
Cornell (College).	Lafayette.	Norwich.	
Haverford.	Maine.*	New Hampshire Agricultural.	
Illinois.*	Michigan Mining School.*	Purdue.*	
Kansas.	Missouri.*	Tennessee.	
Michigan.*	Ohio.*	Utah Agricultural.	
Minnesota.*	Pennsylvania State.		
Nebraska.	South Dakota School of Mines.		
Pennsylvania.	Swarthmore.*		
Stanford.*	Syracuse.		
Washington.	Texas.		
Wisconsin.*	Toronto.*		
14 colleges.		13 colleges.	8 colleges.
		Total, 36 colleges.	1 college.

(e) THE NUMBER IN EACH CLASS THAT SEEM TO HAVE FAIR REGULATIONS.

CLASS A.	CLASS B.	CLASS C.	TOTAL.
9 colleges.	11 colleges.	1 college.	21 colleges.

An analysis of the replies received in regard to this method of admission is given in the following table:

TABLE V.

ADMISSION BY CERTIFICATE.

(a) Those colleges that do not admit on certificate.

	CLASS A 6 COLLEGES.	CLASS B 2 COLLEGES.	CLASS C 2 COLLEGES.	CLASS D 2 COLLEGES.	TOTAL 12 COLLEGES.
Examination plan satisfactory.....	4	1	1	..	6
" " susceptible of extension	1	1	1	..	3

Add Washington and Lee University. No certificates are taken, yet there are no published requirements.

(b) Those colleges that admit on certificate to a small or moderate extent:

	8 COLLEGES.	6 COLLEGES.	2 COLLEGES.	2 COLLEGES.	TOTAL 12 COLLEGES.
Certificate plan satisfactory.....	8	5	1	1	10
" " not satisfactory.....	..	..	1	..	1
No answer.....	..	..	..	1	1
Certificate plan susceptible of extension.....	1	1	..	..	2
Susceptible of extension to a degree.....	1	1	..	..	2
Extension doubtful.....	..	3	2	..	5
No extension desired.....	1	..	..	..	1
No inter-collegiate action desired.....	1	..	..	..	1
No reply as to extension.....	..	..	..	2	2

(c) Those colleges that admit on certificate to some undefined extent.

	6 COLLEGES.	10 COLLEGES.	8 COLLEGES.	2 COLLEGES.	25 COLLEGES.
Certificate plan satisfactory (fairly).....	8	8	2	2	15
" " " (partially).....	1	..	1	..	2
" " not satisfactory.....	1	..	..	..	1
" " no reply.....	..	2	5	..	7
" " susceptible of extension.....	2	8	8	..	8
Extension doubtful.....	..	..	1	..	1
No extension desired.....	..	..	1	..	1
No inter-collegiate action desired.....	1	..	..	..	1
No reply as to extension.....	2	7	2	2	18

(d) Those colleges that admit on certificate to a large extent.

	14 COLLEGES.	15 COLLEGES.	8 COLLEGES.	1 COLLEGE.	36 COLLEGES.
Certificate plan satisfactory (fairly).....	10	10	5	1	26
" " " " (partially).....	1	2	2	...	5
" " not satisfactory.....	2	...	1	...	3
" " no reply.....	1	1	...	...	2
" " susceptible of extension.....	3	8	2	...	18
Extension doubtful.....	...	2	1	...	8
Only within State lines.....	2	...	...	...	2
No extension desired.....	2	1	2	...	5
No inter-collegiate action desired.....	1	...	1	...	2
No reply as to extension.....	8	1	2	1	12
Colleges making no report as to certificates.....	8	8	5	11	22

Nearly every college is satisfied with its own plan. Notice the extent of the practice.

Admitting to a large extent	36	Own plan satisfactory 26	Favoring extension... 15
Admitting to undefined extent.....	25	" " " 15	" " " 8
Admitting to moderate extent.....	12	" " " 10	" " " 8
Not so admitting....	12	" " " 10	" " " 8
No report, including Class E	25		
Total	110		

There are 21 colleges that seem to have fair regulations governing admission by certificate, though there are very few that publish their rules in detail or that have given them in detail to the committee if they exist. The University of California has one of the best and most complete systems. The scheme includes the following points, viz.:

1. Application for accrediting to be on a special blank, showing the subjects on which the school seeks to be accredited, the names of teachers and the subjects taught by them, the number of pupils in each grade, length of school year and terms, etc., and accompanied by sets of actual examination papers and the course of study.
2. Visitation of school by a faculty committee, whose favorable report is essential.
3. Application for accrediting must be renewed annually. Inspection is annual also.
4. Schools are notified of being accredited on special blanks, showing the requirements for different university courses, the courses for which the school may prepare and the subjects for which they can write certificates.
5. Certificate signed by the principal shows the graduation of the candidate, the list of subjects, in each of which the principal recommends, and the course the candidate desires to enter.
6. Lack of above recommendation in any subject to be counted a failure.
7. More than 2 failures, or 1 failure and 2 conditions, or 3 conditions prevents admission.
8. Failure in Algebra and Geometry or Physics and Chemistry prevents admission.
9. Certificates are accepted by a committee, but can only be rejected by the Academic Council.
10. Besides above mentioned blanks, the University issues departmental circulars as occasion arises, containing suggestions as to preparatory work. Also an admission circular of 120 pages containing the following matter: A few pages of general information; extended description of all subjects included in any requirements; requirements for the different University courses; time, place and order of entrance examinations; rules governing examinations; rules for accrediting schools; suggestions regarding preparation for the University; samples of questions previously used for entrance examinations.

11. The University holds conferences on Secondary Education with High Schools and Normal Schools.

Professor Christy speaks well of the working of this system and says that it is the result of a good many years of persistent effort on the part of the University.

The University of Michigan has a similar plan, accrediting schools for three years, using 4 circulars. No. 1, the circular of instructions to the school applying. No. 2, the application showing enrollment, length of course and year, size of library, amount of apparatus and museum collections, character of laboratories, etc., also asking for further information concerning teachers, their length of service, where educated, subjects taught; concerning studies, the text used, the ground covered, time given in weeks and hours per week, and in what grade the subject is taught. No. 3, report of inspecting committee, including statistics of the school and its facilities, a statement of studies pursued, text-books used, time given, grade of work, an estimate of the efficiency of each teacher and a recommendation that graduates be admitted to certain indicated University courses. The inspection may be made by others than members of the faculty, the University delegating its authority to some selected person or persons. No. 4, the certificate showing graduation and detailed list of subjects.

The School of Practical Science, at Toronto, admits the largest part of its students on a government certificate to the effect that the candidate has passed the "high school leaving examination." In the province of Ontario the government conducts these public school examinations.

In New York and adjacent states, the certificates of the New York Regents are taken by some colleges for the ground covered.

Not all of the 21 colleges mentioned above have as complete a method as California or Michigan, but they all require considerably more on the part of a school seeking to be accredited than the mere condition of "being satisfactory to the faculty."

INDIVIDUAL EXPRESSIONS OF OPINION.

5. *Admission by Certificate.* In expressing an opinion as to the present working of the certificate plan, or its extension, many of the committee's correspondents are epigrammatic or answer its questions by a short yes or no. But besides the numerical side shown in the preceding table, one can gather from the general character of the replies that the objections raised are, in many cases, due to dissatisfaction, not so much with the present system, as with its working ; and that those favoring the system do so because of its applicability to existing conditions and its inherent advantages.

6. *Assistance to Preparatory Schools.* Table VI. gives a statistical analysis of the replies to the question as to what help the college can render the preparatory school, and needs no further comment than this ; underlying all replies, with few exceptions, there is shown a spirit of helpfulness and co-operation that argues well for a closer relationship.

TABLE VI.

Assistance that can be given Preparatory Schools by Engineering Colleges.
From replies to college circulars.

	A 31 COLLEGES.	B 33 COLLEGES.	C 26 COLLEGES.	D 18 COLLEGES.	TOTAL 107 COLLEGES.
By raising requirements.....	2	8	...	...	5
By adopting uniform requirements.....	7	4	...	...	11
By urging thorough work.....	1	1	8	...	5
By suggestions and help as to work and methods.....	3	2	2	...	7
By forcing candidates for admission to complete school course	1	...	...	...	1
By working through State Board of Education.....	...	...	1	...	1
By accepting certificates from commissioned schools.....	1	2	1	...	4
By allowing schools to hold entrance examinations.....	...	1	...	...	1
By effort to make them level up to requirements.....	...	1	...	...	1
By personal conference and correspondence.....	8	1	...	...	4
By strict adherence to requirements	2	1	1	...	4
By prescribing a curriculum for them.....	...	2	1	1	4
By encouragement of manual training.....	...	1	...	...	1
By supplying good teachers.....	...	1	...	...	1
By closer touch in associations .....	...	1	...	...	1
By explaining range and extent of required preparation .....	...	2	...	1	3
By more closely connecting college and school courses.....	...	...	1	...	1
By being decided in making demands .....	...	...	1	...	1
Much in every way .....	...	1	...	...	1
"What?" .....	...	1	...	...	1
No belief in co-operation with lower schools.....	1	...	...	...	1
Can render no assistance	1	1	6	1	8
No reply to question	12	14	10	13	49

7. *Considerations governing Changes in Requirements.*—Table VII. needs no comment, as it tells its own story. The replies are consistent throughout, and emphasize the dependence of the college on the school.

TABLE VII.

CONSIDERATIONS CAUSING CHANGES IN ENTRANCE REQUIREMENTS.

From Replies to College Circulars.

	A 81 COLLEGES.	B 33 COLLEGES.	C 26 COLLEGES.	D 18 COLLEGES.	TOTAL 107 COLLEGES.
Condition of preparatory schools.....	10	16	13	2	41
LAW .....	..	..	2	..	2
Requirements of other college departments.....	..	1	..	..	1
Changes in other colleges.....	..	2	1	..	3
Progress in engineering practice.....	1	..	..	..	1
Educational value of studies.....	..	1	..	..	1
Ideal needs and possibilities.....	1	..	..	..	1
Conditions imposed by Civil War.....	..	..	..	..	1
Terms of foundation.....	1	..	..	..	1
Demands of curriculum.....	2	2	1	..	5
Desirability of proposed change.....	..	1	..	..	1
Effect on attendance.....	..	..	2	..	2
Certain preparatory schools connected with college Conference with State Teachers' Association and Methodist University Senate.....	1	..	..	..	1
To give general education along with technical work.....	1	1	..	..	2
To raise standard and broaden scope of the work.....	..	..	1	..	1
To secure general literary education before admission.....	3	..	1	..	4
To secure better prepared students.....	4	2	..	..	6
To secure best preparation in mathematics.....	1	..	..	..	1
To secure elevation of State standards.....	..	1	1	..	2
To secure time for technical work.....	1	2	1	2	6
To secure establishment of State system of united schools and colleges.....	..	..	..	1	1
To maintain a high standard.....	2	..	..	..	2
To make courses as a whole reach up to senior year at Cornell University.....	..	..	1	..	1
To aid students in securing positions after graduation.....	..	1	..	..	1
Policy of the school not to change.....	..	2	..	..	2
Necessity of taking the material offered.....	..	..	..	2	2
Ordinary preparation for science courses sufficient.....	..	1	..	..	1
Present requirements high enough. "Cræze for raising standard is going too far".....	..	..	1	..	1
No answer under this head.....	9	5	7	11	32

8. *Changes desired in Entrance Requirements.* The statistics are given in detail in Table VIII. There are four centers within this table on which the desires of

the colleges are focused, and these in the order of importance in the minds of our correspondents are Mathematics, English, Modern Language and Science. With very few exceptions the requirements desired are just in advance of present standards. Two colleges want Analytical Geometry, which they will probably continue to lack for a long time to come. Of the six colleges that desire Trigonometry, two admit the impossibility of any immediate satisfaction and the others may as well continue to hope. Those wishing an advance in Algebra and Plane Geometry have the elements of Algebra already, with two or three books of Geometry in some cases. Those wanting Solid Geometry now require Algebra through quadratics, and Plane Geometry. This same sequence runs through the English. Where there is a present requirement of grammar or composition, there is a demand for a better working knowledge of the language and some acquaintance with literature. Where a part of the New England Requirements has been attained, there is a desire for the full standard or its equivalent. A very few strong Eastern colleges that already have this ask a further increase.

In the matter of language, the demand for French and German comes from institutions that now have no language requirement. Physics and Chemistry are mainly desired by colleges not now having science requirements.

There is a strong undercurrent in the responses under this head that finds expression in demands for greater breadth and mental grasp on the part of applicants, and this does not come alone from the older

and stronger colleges. It may take definite shape in an expressed wish to build engineering work on a college course, in a complaint over the lack of ability on the part of Freshmen to think independently, or it may net find clear expression, though its presence can be felt.

TABLE VIII.
CHANGES DESIRED IN ENTRANCE REQUIREMENTS.
From Replies to College Circulars.

	A 31 Colleges.	B 38 Colleges.	C 26 Colleges.	D 18 Colleges.	TOTAL 107 COLLEGES.
None.....	3	1	...	...	4
Better preparation in elementary branches, spelling, writing, composition.....	...	1	...	...	1
Time taken from elementary branches and given to Latin, French and Drawing.....	...	1	...	...	1
Gradual elevation of standard.....	...	1	5	1	7
An elective system.....	...	...	1	...	+1=2
Requirements as heavy as for classical courses.....	1	...	...	...	1
Two years of college work as a foundation.....	1	1	...	...	2
Liberal collegiate training to precede engineering work.....	1	...	...	...	1
Better preparatory instruction.....	...	3	2	1	6
To adapt requirements to those obtainable in towns of 8,000 to 10,000.....	1	...	...	...	1
Manual training as a foundation.....	...	1	...	1	2
Freedom from preparatory work.....	...	1	...	...	1
An Examination in candidates' power of application.....	...	1	...	...	1
Knowledge of how to study and think independently.....	...	1	...	...	1
More general culture.....	2	1	1	...	4
Age increased to 17.....	...	...	...	1	1
Drawing.....	1	1	1	...	3
Better work in drawing.....	1	1	1	...	2
English—Better work.....	3	4	2	1	10
Advanced English.....	3	2	1	1	7
More English.....	3	1	3	...	7
Strict enforcement of requirements.....	1	...	...	...	1
History : United States.....	...	...	1	...	1
England.....	...	...	1	...	1
General.....	...	...	1	...	1
More History.....	...	1	...	...	1
Civil Government.....	...	1	...	...	1
Science: Physics.....	2	1	3	1	7
Phys. Laboratory.....	1	...	...	...	1
Advanced Physics.....	2	...	...	...	2
1 year's laboratory work in Phys. or Chem.....	...	1	...	...	1
Chemistry.....	2	...	...	1	3

TABLE VIII.—(CONTINUED.)

	A COLLEGES.	B 33 COLLEGES.	C 26 COLLEGES.	D 18 COLLEGES.	TOTAL 107 COLLEGES.
Some natural science (not Physics).....	...	1	...	...	1
Physical Geography.....	...	1	...	...	1
More work in science.....	1	1	...	...	2
Physiology.....	...	...	...	1	1
Mathematics: Algebra—Elements.....	...	...	...	2	2
Algebra, an advance.....	...	2	4	2	8
Plane Geometry.....	...	1	5	2	8
Solid Geometry.....	1	5	1	1	8
Trigonometry	2	4	...	...	6
Analytical Geometry.....	...	2	...	...	2
Elementary Mechanics	1	1	...	...	2
An advance in Mathematics.....	3	2	1	1	7
Better work in Mathematics.....	3	3	3	...	9
Foreign Languages: French.....	...	1	1	...	2
French or German.....	...	2	...	...	2
“ “ “ 1 year.....	...	1	...	...	1
“ and “ .....	...	1	...	...	1
“ “ “ 1 year each.....	...	1	...	...	1
“ or “ 2 years.....	...	2	...	...	2
Modern Language.....	...	1	...	...	1
German or Latin.....	...	1	...	...	1
Latin, 2 years.....	...	1	...	...	1
Less Latin.....	...	1	...	...	1
Omission of Latin.....	1	...	1	...	2
Ancient or Modern Language 1 year.....	...	...	1	...	1
More Language.....	3	1	...	...	4
Better work in Language.....	2	...	...	...	2
No answer as to changes desired.....	11	8	10	11	40

9. *Uniformity of Requirements.*—The tabulation below gives a summary of the replies under this head.

CLASS.	A	B	C	D	TOTAL.
Desirable to some extent.....	17	18	10	4	49
Not desirable	6	5	8	1	15
Practicable to some extent.....	8	14	4	2	28
Not practicable.....	8	9	13	2	32

The replies as a whole are quite decidedly favorable to the abstract idea of uniformity, though the belief in its practicability is not so general. Here again the answers, many of them, were confined to monosyllables or were given in more or less uncertain terms. This is a very natural result, because no definite plan of action was presented for consideration and because of a lack of practical experience with any scheme involving it. The general spirit of the replies can perhaps be understood through the following quotations, the larger number of which relate to this topic.

10. *Quotations from the College Circulars.*—

“As far as possible all entrance examinations should be assimilated.”—MC GILL UNIVERSITY.

“It is desirable. With concerted action on the part of the engineering colleges, it can be made practicable in time—how soon, will vary in different sections.”—MAINE STATE COLLEGE.

“It seems to me desirable to have very thorough examinations on standard and essential specifications made nearly uniform. The thoroughness of the entrance examinations to the United States Military Academy is worthy of imitation.”—THAYER SCHOOL OF CIVIL ENGINEERING.

“There is very little that appeals to me in the idea of educational uniformity. The critical thing is the degree of the candidate’s achievement and attainment.”—NEW HAMPSHIRE AGRICULTURAL COLLEGE.

“In the present varied condition of work in preparatory schools, whose standards differ so widely in different parts of the country, I do not think much can be done in this direction.”—WORCESTER POLYTECHNIC.

“There should be a certain minimum standard to which all schools should endeavor to attain. The work in preparatory

schools will be greatly facilitated if the requirements should consist of the same subjects, though the extent might be different for different schools."—MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

"Uniformity cannot be desirable or practicable until there is greater unanimity of opinion in regard to methods of teaching. There is danger of running to the extreme and crushing out individuality in the public schools."—BROWN UNIVERSITY.

"Very desirable as an aid to the work of the preparatory schools."—SHEFFIELD SCIENTIFIC SCHOOL.

"Both desirable and practicable that this society should formulate and offer, after careful consideration, three or possibly more grades of minimum requirements, to be styled the S. P. E. E. requirements for entrance, Grade I, Grade II, etc.; either of which engineering colleges should be free to adopt as their minimum requirements, according to their respective ability to maintain them. This society might further offer incentive and encouragement to engineering colleges by announcing annually lists of the colleges having adopted either of the Grades."

—UNION UNIVERSITY.

"That the requirements for admission to different engineering colleges be made uniform, is neither practicable nor desirable, but that requirements in a given common subject be made identical in kind, though not necessarily in extent, is both practicable and desirable."—COLUMBIA SCHOOL OF MINES.

"The courses of the different engineering colleges are so much at variance that uniformity of requirements does not seem to be desirable or practicable."—STEVENS INSTITUTE.

"The question of what is the ideal engineering education, has not yet been answered satisfactorily and the answer can only be had from actual experience. Hence it is not desirable for all colleges of engineering to follow the same plan; rather let each follow what seems best in the circumstances in which it is placed."—J. C. GREEN SCHOOL OF SCIENCE.

“Neither desirable nor practicable.”—UNIVERSITY OF PENNSYLVANIA (SPANGER).

“It would be desirable if our leading engineering colleges could be brought to a substantial agreement on the question of entrance requirements.”—UNIVERSITY OF PENNSYLVANIA (MARBURG).

“Our technical professors are not inclined to think that such assimilation, as an end in itself, is especially desirable. The rivalry between the foremost colleges brings about a kind of self-acting adjustment which acts to some extent in the direction of uniformity, but it is doubted whether anything further than this is beneficial.”—LEHIGH UNIVERSITY.

“Preparatory schools would be glad to know very exactly the kind and extent of preparation required. No uniform standard for the whole country is practicable. But if the engineering colleges can fix and grade their own work, *stage by stage*, and then show what preparation will be required for each stages (including one Sub-Freshman year), different preparatory schools will see just what stage their students can aim to reach, and all would gradually try to reach the highest.”—PENNSYLVANIA STATE COLLEGE.

“It is desirable, but impracticable, except to a degree; local conditions governing fitting schools being an important factor that cannot be absolutely controlled by higher institutions. A co-operative effort to secure this desired result would in the end produce good results.”—PURDUE UNIVERSITY.

“There should be a general understanding that the general education, comprising that offered by the best high schools, should have been completed before admission to engineering colleges. Each engineering college must however be given some freedom of requirements as each must have some peculiarity.”—ROSE POLYTECHNIC.

“Very desirable. See no reason why it is not practicable.”—UNIVERSITY OF ILLINOIS.

"Desirable, but not practicable until the engineering colleges are more evenly graded."—MICHIGAN AGRICULTURAL COLLEGE.

"When the localities, constituency, objects and fitting schools are uniform, then the requirements can be made the same for entrance, but not before. Each college must harmonize with its own environment, and the education it requires or gives must be adapted to the college surroundings, or it fails."—MICHIGAN MINING SCHOOL.

"It may be quite desirable to assimilate the requirements, but as this institution cannot be separated from the school system of the State, it is impossible to do anything here in this line."—UNIVERSITY OF WISCONSIN.

"Very desirable in order to give to preparatory schools a common standard (approximately) to work to. Otherwise they ignore our wants since they are so various."—WASHINGTON UNIVERSITY.

"Doubtful. Such assimilation of requirements would, however, make it possible to judge of the rank of a college from a statement of its entrance requirements (provided it is known how strictly they are enforced). This parenthetical clause brings up a question intimately related to and fully as important as the main one."—UNIVERSITY OF NEBRASKA.

"They should be identical in kind and extent. The degree should always mean the same thing."—UNIVERSITY OF COLORADO.

"I don't think it will work. New England with its old preparatory schools can insist on a high standard of entrance, while we must have a lower standard, but insist on a *high* standard of graduation."—UNIVERSITY OF TEXAS.

"It is desirable that the admission requirements be identical to the extent that a student preparing for one engineering college may be prepared so far as his preparation has extended to enter any other college. This may be an advantage to the student as he may see fit to make a change in the selection of a

college which he may finally decide to attend."—UNIVERSITY OF UTAH.

"Had we all the same advantages, it would undoubtedly be a great advantage to standardize not only the requirements for admission, but also, as far as possible, the courses of instruction. But under the great diversity of circumstances, it would be practically impossible to establish such a course in some communities where engineering instruction is most needed. We candidly admit that we cannot adopt the standard of some older and better equipped colleges at present. It might be well to standardize the *individual branches* over a sufficiently broad range to include the requirements for admission of all engineering colleges."—UTAH AGRICULTURAL COLLEGE.

"It is both desirable and practical that the entrance requirements be identical in kind. This opinion is based upon the uniform nature, technically and practically, of all engineering courses."—NEVADA STATE UNIVERSITY.

"I do not consider it of much importance whether the requirements for admission are similar or not. It is more important that the requirements for degrees be somewhat uniform in different colleges."—UNIVERSITY OF IDAHO.

"Uniformity should be the aim for all, but at the present time it would be folly for some of the Western institutions to adopt the requirements that Columbia and other institutions can maintain."—NEW MEXICO SCHOOL OF MINES.

"Do not think it very essential that entrance requirements should be the same, and am certain that it is entirely impracticable to have them the same in kind in the South."—VIRGINIA AGRICULTURAL COLLEGE.

"I don't think it a matter of great importance that the requirements should be uniform except for English and Mathematics."—WASHINGTON AND LEE.

"Desirable, but not at present feasible or practicable. It necessitates uniformity of preparatory and high schools

throughout the State. It is not even possible to have admission requirements identical in kind, such as French, even if variable in extent. A uniform *minimum* requirement is both practicable and possible. Then if a candidate possessed more than this *minimum*, he could be given advanced standing commensurate with his qualifications."—WEST VIRGINIA UNIVERSITY.

"I think it desirable to have the requirements for admission to different engineering colleges identical; but such a plan is not practicable. Our public schools vary so much in methods and subjects taught, that the entrance examinations into our various colleges must depend largely upon local conditions."—KENTUCKY STATE COLLEGE.

"This is very desirable and is entirely practicable—within limits."—VANDERBILT UNIVERSITY.

"Uniformity of requirements is only desirable in so far as it promotes uniformity of courses. A student always knows what college he wishes to enter and can prepare himself accordingly, but if he desires to change or enter a higher institution, much of his work, while valuable in itself, may help him very little in the new position."—ALABAMA POLYTECHNIC.

"They should be identical in kind and extent so far as local conditions will permit. This for the sake chiefly of the effect on the secondary schools."—ARKANSAS INDUSTRIAL UNIVERSITY.

"The general range of subjects required for admission to different engineering colleges should be about the same, though local causes will influence the kind and extent of preparation attained in the different individual subjects."—MISSISSIPPI AGRICULTURAL AND MECHANICAL COLLEGE.

A few quotations are given below relating to other subjects than uniformity.

"We are now proposing to compel all students to take at least two full years in the Faculty of Arts before they are al-

lowed to commence their work in any of the engineering departments, and we hope that within a few years we may be able to require the A.B. degree from all candidates for admission into the Faculty of Applied Science."—MCGILL UNIVERSITY.

"A candidate for the degree of C.E. or M.E. ought to be a college graduate. That is, courses leading to these degrees ought to be graduate courses."—BROWN UNIVERSITY.

"I judge that this system of approved schools, tried here for two years, has been of great use in moulding the courses of the schools. I have found them anxious for suggestions and ready to adopt them."—MAINE STATE COLLEGE.

"I should not favor any system which would pass students by certificate from one institution to another."—SHEFFIELD SCIENTIFIC SCHOOL.

"It is the aim of the college to take the student as far as possible in mathematics and engineering; for this reason all subjects which can be taught well in the preparatory schools should be thrown into the requirements for admission."—RUTGERS COLLEGE.

The college is guided by—"In making changes, the elevation of standard of education in the State—in not making changes, a desire to keep in reach of public high schools. Being a land grant college, we recognize this close relation."—DELAWARE COLLEGE.

"Changes are desirable in the direction of bringing requirements to the preparation obtainable in public schools of 8,000 to 10,000 inhabitants. Preparatory schools should not be cultivated at the expense of the public school system. As they are paid for this work, they should put their schools on any basis their patrons may demand."—UNIVERSITY OF PENNSYLVANIA (Spangler).

"A grade of secondary technical schools seems to be greatly needed as feeders to engineering courses, in which the instruc-

tion should be given by teachers in sympathy with engineering methods.”—SWARTHMORE COLLEGE.

“Changes are desired in the direction of more thorough and exacting *drill* in the fundamentals. A great deal of the preparatory work offered lacks definiteness of detail. Many of the secondary schools are sacrificing thoroughness to *spread*. They are more and more teaching habits of observation and reasoning, but are not sufficiently enforcing a habit of *fixing* and *formulating* results.”—PENNSYLVANIA STATE COLLEGE.

“Intercollegiate action in favor of a high standard in the quality of the preparation would doubtless improve the system (certificate), but would almost certainly restrict rather than extend it.”—OHIO UNIVERSITY.

“We want a higher grade of mark rather than an indifferent mark in more advanced studies. Good elementary instruction rather than poor instruction in higher branches.”—ROSE POLYTECHNIC.

Concerning extension of certificate plan, “Probably not much beyond State lines, and then only for institutions of large reputation.”—UNIVERSITY OF ILLINOIS.

“It seems that much good could be done by a co-operative system (certificate), particularly by each engineering college reporting to others the grade and standing of their local schools.”

“As this is a State college, its duty is to take students after they have completed their course in the other educational institutions of the State, *i. e.*, high schools, colleges and university. It is therefore obliged to start from the plane of the high school. The special subjects demanded for entrance are determined by our needs as a professional college, as we make no pretense of giving a general education.”—MICHIGAN MINING SCHOOL.

“In Iowa, an open field exists for co-operation between the public schools and this college, which should result in the elevation of the standard in the former and the acquisition of better prepared students by the latter.”

"It (certificate plan) ought to be limited rather than extended until the schools of this State are more evenly graded."—**IOWA AGRICULTURAL COLLEGE.**

"Requirements for engineering courses should be as heavy as are now demanded for classical course, only allowing the substitution of modern language or science for the ancient languages."—**CORNELL COLLEGE.**

As to extension of certificate plan, "Decidedly so; and possibly herein lies the greatest need of inter-collegiate action."—**WEST VIRGINIA UNIVERSITY.**

"For our engineering work, the main preparatory training required is in mathematics. Students come to us with various degrees of proficiency in that subject, but I think one general criticism is justified; they are almost always weak on the geometrical side, having been trained to a sort of mechanical dexterity in arithmetical and algebraic work, and knowing the ordinary theorems of geometry tolerably well, but greatly lacking in the power of geometrical reasoning for the simple reason that they are not forced to solve problems geometrically. I consider this the improvement most to be desired in the elementary teaching of mathematics in this section of the country."

—**UNIVERSITY OF VIRGINIA.**

B. REPLIES FROM SCHOOLS.

The information asked for from schools was expressed in the circular under the following heads, viz:

1. What are your present facilities for preparing students for admission to engineering colleges (or to any particular engineering college) in Mathematics, English, History, Foreign (including Ancient and Modern) Languages, Natural and Physical Science (with or without laboratory instruction) and Shop-work and Drawing? Statements as to ground covered, time given to the different subjects, *particularly Mathematics*, material equipment in the way of laboratories, apparatus, shops, etc., are desired.
2. (a) What is the length of your preparatory course or courses, and what is the average age of your graduates? (b) Do you advise your graduates to devote additional time to preparation before entering an engineering college?
3. (a) What advance in requirements, if any, would it be practicable for you to meet? (b) Do you consider such an advance desirable?
4. To what extent would it assist you if engineering colleges should make their requirements more nearly uniform, *i. e.*, in the sense that requirements in a given subject should, so far as they go, cover the same ground for all engineering colleges requiring them at all?
5. Do you desire to recommend an extension (or the reverse) of admission by certificate?

The questions of the School Circular were designed to draw out expressions of opinion on the various questions raised rather than such precise information

as should admit of tabular statement. At the same time the questions were made as definite as was consistent with brevity, in order to facilitate the comparative study of the replies.

1. *Present Facilities, etc.*—It is quite impossible to base on replies to this question any exact comparison of the quality and extent of the preparatory work in particular subjects even of those schools reporting most fully. The real value of any general tabulation would, moreover, be greatly impaired by the very unequal numerical representation of different sections of the country, a difficulty not otherwise very important. Taking these factors into account the following statements may be regarded as approximately correct.

Of the schools reporting :

nearly two-thirds teach Solid Geometry ;
about one-half teach Trigonometry ;
about three-fourths teach French or German, less than one-half French and German ;
more than two-thirds offer laboratory instruction in Chemistry or Physics or both ;
but comparatively few give laboratory instruction Natural Science ;
about one-half mention Drawing, one in seven Shopwork.

2. *Course and Age.* (a) The average age is naturally about 18, the average length of course 4 years. Both vary with the college requirements, many schools remarking that their students can and do enter engineering schools without completing their own course. (See 3.)

(b) Additional time is not generally advised, although

this may indicate merely good local articulation rather than intrinsic adequacy of preparation.

3. *Advance in Requirements.* Replies to this question can be dealt with only qualitatively. A particular requirement may be an undesirable advance in one place, a desirable one in another, an accepted fact in a third. Notable tendencies represented are to require:

(a) Solid Geometry or Trigonometry. "If less Geometry were required, and more Trigonometry, we think it would be a good thing. The Trigonometry is most useful in giving boys an idea of what it is all for."

(b) Laboratory work in Science.

(c) Better general training, *e. g.*, Latin.

In general the better schools urge emphatically that requirements for engineering schools be made as exacting as for other colleges.

"The low standard of requirement for admission is the most serious obstacle the preparatory schools have to encounter."—**BRIDGEPORT (ALA.) TRAINING SCHOOL.**

"At present I think that it must be conceded that the requirements for admission to our best colleges call for better and more mature training than is called for by our best schools of science."—**BELMONT (CAL.) SCHOOL.**

"Scientific schools in the West sometimes take our boys before they graduate, much to our disgust in some instances. A four year's preparatory course should be required"—**HIGH SCHOOL, SPRINGFIELD, ILL.**

"The requirements of scientific colleges almost without exception lead to courses not well rounded and fitted to *educate*." (The writer advocates requirements of Latin, Chemistry, Physics.)—**HIGH SCHOOL, WALTHAM, MASS.**

"Schools of engineering usually entice our boys when they are only half or three quarters through the school. Over and over again I have been saying to this type of professional school

that they need, more than anything else, more exacting requirements. In several institutions with which I am very familiar the morale of the school of engineering is far away the worst in the place, and this in my judgment is directly traceable to the unsifted material which finds admission."—LAWRENCEVILLE SCHOOL, LAWRENCEVILLE, N. J.

"The technical schools are already so high in their requirements that they make our preparatory classes so small that they are very expensive. It would be better for technical schools to give more time, if necessary, rather than require more of preparatory schools. It is a mistake for technical schools or colleges to get too far removed from the masses."—STATE NORMAL AND MODEL SCHOOL, TRENTON, N. J.

"Requirements can only be advanced at the expense of thoroughness." "Graduates of preparatory schools should not be expected to do at once *university* work."—HIGH SCHOOL, WATERTOWN, N. Y.

"We would meet any reasonable advance, but would protest against it as unwise."—ABINGTON FRIENDS SCHOOL, JENKINTOWN, PA.

In general the sentiment is that the colleges should not make their requirements so high as to demand much more work than the schools now do, or so low that much less work would suffice for admission. The better colleges do not perhaps appreciate the necessity, or even the difficulty, of adapting requirements to the capacity of the country schools.

4. *Uniformity of Requirements.* The real center of gravity of the circular and of the replies lies in No. 4. The approval of uniformity is practically unanimous. The urgency of the demand for it varies greatly in different schools. Most country high schools have to concern themselves with only one engineering college, and are, therefore, little concerned as to uniformity.

A few exceptionally strong—possibly not over modest schools—ever that they give enough preparation for any engineering college, and have therefore, nothing to gain by uniformity. A brief consideration of the Committee's table of *all* requirements (Table I.) would perhaps shake their confidence.

Specimen replies to this question may be quoted, to illustrate different aspects of the matter.

"I can think of no movement that would be of such service to secondary schools as to have the requirements for admission more nearly uniform. I do not hesitate simply to decline to meet the requirements of engineering schools when they depart seriously from the requirements that seem to be normal, and I unhesitatingly advise my boys to go to one of the schools whose requirements for admission conform to the normal. Uniformity seems to me as important to schools of engineering as to the secondary schools for it would leave pupils free to choose on the merits of the institution."—BELMONT (CAL.) SCHOOL.

"We have comparatively few pupils that have so far looked in the direction of engineering. Doubtless such a work as you are attempting will help to direct their attention that way."—PETALUNA (CAL.) HIGH SCHOOL.

"Such uniformity would hasten the adoption of improved facilities for meeting them."—SAN DIEGO (CAL.) HIGH SCHOOL.

"If the requirements of engineering schools were more uniform it would save us a great deal of individual work."—CALIFORNIA SCHOOL OF MECHANIC ARTS.

"The position that the colleges have taken towards each other and the public is ludicrous from any standpoint, in connection with the preparatory schools. There must be general requirements for the fitting of young men for scientific schools, here as in Europe."—BATES ACADEMY, SAN RAFAEL, CAL.

"It would help us greatly and give us something definite to

work to, and be a reward for stated work. The tendency is to scatter our work and not get best results."—SUPERINTENDENT, PUEBLO, COLO.

"The engineering schools themselves would be far better provided for."—NEW BRITAIN (CONN.) HIGH SCHOOL.

"In proportion to the diversity of requirements the students' preparation will be poor."—SIDWELL'S FRIENDS SCHOOL, WASHINGTON, D. C.

Uniformity "not essential. We try to know at least two years in advance the student's plans, what college he will enter etc., and fit him for the particular institution."—CENTRAL HIGH SCHOOL, WASHINGTON, D. C.

Uniformity "desirable, because giving us a *definite piece of work to do*. When requirements vary, we do either too much or too little."—HIGH SCHOOL, SPRINGFIELD, ILL.

"It would aid materially as we could then allow our students to elect studies for the engineering schools and omit studies from our course not needed for admission to such schools. At present the preparation has to be general, as to meet the requirements of all the schools would call for an instructor for each student."—ENGLISH HIGH AND MANUAL TRAINING SCHOOL, CHICAGO, ILL.

"It would be the wisest thing the colleges were ever guilty of. As it is, the state institutions require just enough to preclude the possibility of preparing for any *other* college but their own. A little uniformity would enable emigration without such a sad interference with school arrangements."—HIGH SCHOOL, LEAVENWORTH, KANS.

"Uniformity in requirements for admittance to higher institutions generally, would assist in unifying the work of secondary schools. It would enable such schools to measure their work by that of others, and would stimulate pupils to remain and prepare for some college of their choice."—HIGH SCHOOL, SENECA, KANS.

"The engineering schools ought to get together on the requirements, particularly in languages and sciences. The agreement in mathematics is closer already. Hardly anything would help the schools (secondary), and the colleges (scientific) so much, mutually."—PHILLIPS ACADEMY, ANDOVER, MASS.

"Each year boys will change their plans from one college to another, and, so far as examinations go, that sets them back badly. If uniform for colleges and scientific schools it would be a great benefit."—POWDER POINT SCHOOL, DUXBURY, MASS.

"It would aid me in my work if *colleges and engineering schools* should make their requirements more nearly uniform in the sense suggested."—HIGH SCHOOL, MALDEN, MASS.

"It would be of great assistance if the requirements should be kept in line with college requirements, with options in the natural sciences so far as we are prepared to offer them."—HIGH SCHOOL, MEDFORD, MASS.

"A great advantage to us in making our programmes, and, as a consequence, more boys would enter upon courses of study in higher institutions."—HIGH SCHOOL, NEWTON, MASS.

"Ill betide the young man whose plans for entering one institution have to be modified to meet the requirements of another."—HIGH SCHOOL, QUINCY, MASS.

"It would, however, help us very much if this kind of uniformity in requirements should be established between the scientific schools and colleges."—HIGH SCHOOL, SALEM, MASS.

"I fully believe that the great cause of education would be benefitted by uniform requirements for scientific schools, by a uniform examination paper under the charge of a commission of the various schools of technology and heads of secondary schools."—BRISTOL ACADEMY, TAUNTON, MASS.

"I think that uniformity in requirements will compel systematic work in all preparatory schools."—CENTRAL HIGH SCHOOL, MINNEAPOLIS, MINN.

“Uniform requirements assist very materially in preparing for any school. I know it would especially assist in preparing for an engineering school.”—CITY HIGH SCHOOL, ASHLAND, NEB.

“It would lead to better work on the part of all engineering pupils. Some now need to do so little to get into certain schools that they are lured to idle away time. Easy admission tends to put my poorest pupils into those schools, and indirectly affects all the work of the school.”—HIGH SCHOOL, HINSDALE, N. H.

“It would enable us to concentrate our teaching upon those requirements, and we would not be obliged to have several teachers giving instruction in different subjects to meet special requirements of particular schools.”—HIGH SCHOOL, MANCHESTER, N. H.

“Uniformity has come to be almost a necessity if the secondary schools are to do the best possible for the colleges and scientific schools. It would be an excellent scheme if representatives from a few of the leading schools would get together and constitute a uniform programme. Schoolmasters should be represented in such conferences.—PUBLIC HIGH SCHOOL, MONTCLAIR, N. J.

“Speed the day when there shall be some general uniformity. If your schools will be nearly uniform in the subjects required, you will get pupils much better prepared.”—HIGH SCHOOL, NEWARK, N. J.

“We are compelled to split classes, lose time, and make part of the work partake of the nature of a ‘cram.’”—DEARBORN-MORGAN SCHOOL, ORANGE, N. J.

“If technical schools would agree upon a uniform standard of requirements, secondary schools would gradually make their courses of study conform to that standard.”—HIGH SCHOOL, ALBANY, N. Y.

"With such a definite and uniform aim, special classes could be organized earlier in the course, with less conflict, disappointment, and crowding of subjects in senior year."—HIGH SCHOOL, BUFFALO, N. Y.

"In a general way, I think it would emphasize the engineering course and induce us to arrange our courses with reference to such schools."—WARSAW UNION AND ACADEMY, WARSAW, N. Y.

"It would be of very great help to us, but of far greater help to the engineering schools themselves. The wide-awake teacher often has a chance to send a really bright boy to a higher institution of learning, if he is ready to go when he leaves the school."—HIGH SCHOOL, WATERTOWN, N. Y.

"If engineering schools should make their entrance more nearly uniform, our school would try to arrange to meet them in every respect. We would then be prepared to speak authoritatively to our Board of Education as to what ought to be taught and what omitted in our course leading to scientific schools."—HIGH SCHOOL, ASHTABULA, O.

"The greatest and best help to be given to secondary schools, particularly to the public high schools."—HIGH SCHOOL, HEPPNER, OREG.

"It would make it easier for us to show the Board of Education what advance was necessary in our work."—HIGH SCHOOL, COLUMBIA, PA.

"Such uniformity would enable progressive men in back-woods districts to raise and maintain higher standards in both public and private schools by sheer authority. There is danger, however, of specialists' regarding the public schools as preparatory schools to colleges, dealing with their specialty only; and so of their expecting too much of such schools."—PUBLIC HIGH SCHOOL, AUSTIN, TEX.

"I believe that the higher institutions will best subserve their own interests and those of the body of students they seek

to serve by adapting their requirements to the capacity of any high school of thorough methods and high standards."—FREE HIGH SCHOOL, BELOIT, WIS.

5. *Admission by Certificate.* Hardly less momentous, probably not less difficult than the problem of uniformity is that of admission by certificate. The relative unanimity of sentiment on the former is here, however, conspicuously lacking. The weight of opinion is unquestionably favorable to a careful extension of the certificate system. Moreover many of the objections appear to apply to incidental defects or even abuses of the system. Nearly all the objections come from schools which from their location have least to do with the certificate system—or know it only through experience with the weaker colleges, to which in certain districts it is confined. Here again, let the schools speak for themselves.

"I am heartily opposed to an extension of the system of admission by certificate. This can benefit only the preparatory schools that do inferior work."—BRIDGEPORT (ALA.) TRAINING SCHOOL.

"If there were some system of accrediting that would eliminate poor schools, I should like to see the system extended, but "there is always a strong temptation to admit rather indiscriminately and thus leave the best schools without any distinguishing mark."—BELMONT (CAL.) SCHOOL.

"I believe in the system, but think it should be supplemented by examination. That is, both the school and the student coming from it should be examined. Of course the examination given to accredited pupils should differ from the tests required of those not accredited."—CALIFORNIA SCHOOL OF MECHANIC ARTS.

"I am very much opposed to the system of admission by cer-

tificate. The character of the student for grasp, for accuracy, for industry and ability ought to have weight with an examining board, but only as any other paper that a student presents."—**BATES ACADEMY, SAN RAFAEL, CAL.**

"I believe that in the end admission by certificate will secure better work from the high schools than admission by examination."—**DENVER, (COLO.) HIGH SCHOOL I.**

"It would be beneficial to both classes of educational institutions and save the student a large amount of trouble and worry, which usually are entirely unnecessary."—**DENVER, (COLO.) HIGH SCHOOL II.**

"Boys who fear no entrance examination do not seem to keep up to the work to the end."—**JARVIS HALL MILITARY ACADEMY, DENVER, COLO.**

"I believe in admission upon the *individual* recommendation of the principal. I do not believe in admission by the diploma of graduation."—**DURANGO, (COLO.) HIGH SCHOOL.**

"While it is a sort of motive that a teacher can bring to bear *sometimes* upon an indifferent pupil, that he has an examination at college to pass, I have found in my experience that admission by certificate works no harm. I insist upon thorough work to the end, or no certificate."—**NEW BRITAIN, (CONN.) HIGH SCHOOL.**

"We prefer to have the examinations given by others."—**SIDWELL'S FRIENDS SCHOOL, WASHINGTON, D. C.**

"The most satisfactory results are obtained by rigid entrance examinations."—**CENTRAL HIGH SCHOOL, WASHINGTON, D. C.**

"I believe the preparatory school is a much more intelligent judge of a student's preparation than the college; and yet I do not feel sure that the preparatory schools are ready to assume the responsibility involved in a general admission by certificate."—**WESTERN MILITARY ACADEMY, UPPER ALTON, ILL.**

"Sets of questions ought to be sent even to all approved

schools. Schools think they are better than they really are oftentimes."—HIGH SCHOOL, KEWANEE, ILL.

"As soon as any high school proves its ability to do first-class preparatory work, I believe the college or university so situated as to be best able to determine this should place the school on the accredited list; and that other institutions for higher learning should accept such judgment as satisfactory, and give the school recognition."—HIGH SCHOOL, LAWRENCE, KANS.

"Let the school that desires admission by certificate be subjected to an examination, and if satisfactory, let it be placed on the approved list, to make yearly reports to such colleges as recognize it. This system has increased the value of our work, and the number that yearly go to college."—HIGH SCHOOL, LEAVENWORTH, KANS.

"A careful study of the high schools and academies by the college, and vice versa, followed by an extension of the system of admission by certificate, we heartily endorse. We know we *can* and *do* fit better for those institutions which accept our certificate. Under such circumstances, we can hold the pupil until he has a broader training than the mere requirements of the institution in view; and until he has mastered not the *sample examination papers* of the college selected, but the *subjects* he presents."—FRIENDS ELEMENTARY AND HIGH SCHOOL, BALTIMORE, MD.

"Examinations are only a safeguard against the ignorance and the timidity of the secondary schools. Some teachers do not know what the scientific courses require in attainments and power; others are constrained to overestimate the pupil's proficiency by local and personal considerations."—PHILLIPS ACADEMY, ANDOVER, MASS.

"I desire very much that the system of admission by certificate—under, of course, proper restrictions and conditions—should be generally adopted. It would save a good deal of time now spent in reviewing for the *sole* purpose of passing the ad-

mission examinations. It would also in my opinion be a fairer test of a candidate's qualifications."—HALE'S SCHOOL, BOSTON, MASS.

"I should prefer that the responsibility of admission to the technical schools should rest with the schools themselves. I am always glad to give all information in my possession concerning the qualifications of examinees, and think that in doubtful cases it would be well to get my opinion."—ENGLISH HIGH SCHOOL, BOSTON, MASS.

"I think the principal of a preparatory school is the best judge of the fitness of his graduates for further study, being able to draw evidence from four years of time and from a number of assistants who have observed the boy's progress under natural conditions."—ENGLISH HIGH SCHOOL, CAMBRIDGE, MASS.

"I refuse to give a certificate in the few cases where I can. I however, believe very thoroughly in a system like the Regents' examinations in New York for elementary subjects under management of colleges. It is hard to get parents or pupils to have good work done in these subjects."—POWDER POINT SCHOOL, DUXBURY, MASS.

"We would rather have all our students take the examination and thus relieve us of all responsibility."—DEAN ACADEMY, FRANKLIN, MASS.

"Admission by certificate is necessarily detrimental to all parties concerned. Pupils should take to their entrance examinations all the written work which they have done in the preparatory school with teachers' corrections and suggestions."—HIGH SCHOOL, MALDEN, MASS.

"We do not believe in 'the system of admission by certificate.' In general the preparation for an examination seems to have a beneficial influence upon the character and scholarship of our pupils."—HIGH SCHOOL, NEWTON, MASS.

"I think that the examination system develops better scholar

ship, but that examiners should be very judicious in their questions."—HIGH SCHOOL, QUINCY, MASS.

"The present method of written tests by strange people in strange places is a poor criterion of fitness."—HIGH SCHOOL, SALEM, MASS.

"I have watched this certificate matter for a long time; have written scores of them. It has *always* made the pupil lazier to know he could enter by certificate. In the minds of pupils it is a confession of inferiority to go to an institution that admits by certificate. Finally, it is not honest that a man should audit his own books."—BRISTOL ACADEMY, TAUNTON, MASS.

"It puts the preparatory school in close touch with the college, and *undoubtedly* opens the way for many pupils who otherwise would not go to a higher institution of learning."—HIGH SCHOOL, DULUTH, MINN.

"I recommend the extension of the system of admission by certificate, because I believe that many timid pupils of ability would fail on an examination given by strangers or in an unfamiliar environment. These may be fully prepared to meet every demand of the college, once in."—CENTRAL HIGH SCHOOL, KANSAS CITY, Mo.

"I think the certificate should be used chiefly for the benefit of the more mature student, who has ability, but who has been compelled to make his preparation hurriedly."—RUGBY ACADEMY, ST. LOUIS, Mo.

"The schools of engineering that accept certificates will probably get the most pupils. The schools offering certificates bring themselves into very close touch with pupils seeking a school. Personally, I would prefer to have my pupils examined by judicious examiners."—SMITH ACADEMY, ST. LOUIS, Mo.

"The system of admission by certificate should be extended to all schools doing honest and thorough work, after careful examination by competent persons of the work actually accomplished."—FRANKLIN ACADEMY, FRANKLIN, NEB.

"I would advocate admission only upon examination, allowing certificates to have weight, according to merit of institution granting them, in judgment of papers."—HIGH SCHOOL, GRAND ISLAND, NEB.

"I hope that in time admission by certificate may be the rule. For many reasons all steps in this direction must be made slowly and cautiously. Haste in admitting by certificate would lower the standard of scholarship seriously. It seems to me, however, that secondary schools are taking such steps that in time certificates may be safely used."—PHILLIPS ACADEMY, EXETER, N. H.

"I do not consider entrance on examination just to the pupil. His teachers *should* give his examinations and know his true attainments."—HIGH SCHOOL, HINSDALE, N. H.

"I prefer to have my graduates enter college by examination. I appreciate the relief given to those who enter by certificate from anxiety and nervous strain, but I believe a school which had a reputation of preparing students well would afford its pupils the same relief."—HIGH SCHOOL, MANCHESTER, N. H.

"When we reach an ideal condition in our educational system, admission by certificate will be the natural and proper plan. At present I should be willing to see a very cautious extension of the system."—PUBLIC HIGH SCHOOL, MONTCLAIR, N. J.

"In my opinion the time is not ripe for admission by certificate. I should recommend some improvement in the form of carrying on examinations. They should be accompanied by a full explanation (confidential) from the previous instructor."—DEARBORN-MORGAN SCHOOL, ORANGE, N. J.

"An extension. Otherwise students who have been good in elementary branches must draw off time from *higher* work for review on unnecessary details."—STATE NORMAL AND MODEL SCHOOL, TRENTON, N. J.

"Colleges and technical schools have sought to extend it and at the same time 'hedge it about' till in most cases it consists

in answering a lot of useless questions as to 'what text-books were used,' etc. When the colleges said 'Here are our requirements,' and the principal of the secondary school said 'The following named have fulfilled them,' it was a good system with a *ready remedy* for those who were disposed to be dishonest."—
HIGH SCHOOL, ALBANY, N. Y.

"If a high standard is maintained by a secondary school, no evil will result from the certificate system. The higher institutions, it seems to me, must deal with secondary schools as so many independent individuals. Certificates from a good school should be accepted and certificates from a poor or untried school should be given especial consideration as to their value."—
BOYS' HIGH SCHOOL, BROOKLYN, N. Y.

"I desire and recommend universal admission to college upon certificate from all schools that maintain a four years' course of study above the grammar grade. Such a four years' course might be inspected and approved by a Board of Inspection representing associated colleges and professional schools."—ADELPHI ACADEMY, BROOKLYN, N. Y.

"We advocate solid preparatory work followed by graduation; then admission by certificate in laboratory or technical subjects and mathematics; in others, examination."—HIGH SCHOOL, BUFFALO, N. Y.

"Yes, but swift and certain punishment must be given to schools or principals whose certificates do not properly certify."—UNION SCHOOL, CANANDAIGUA, N. Y.

"I recommend that some system be adopted by our colleges and scientific schools, so that all boys and girls who really desire to enter may do so, provided they have completed any good four years' high school course."—HIGH SCHOOL, ITHACA, N. Y.

"An extension—under suitable limitations. Yet the prospect of an entrance examination is sometimes a most valuable spur, and more effective than the usually too confident expecta-

tion of graduation from the preparatory school."—FRIENDS' SEMINARY, NEW YORK, N. Y.

"I believe in certificates, but * * * my associates in the work are not ready for certificates. I believe no harm will result, but much benefit if all colleges would accept these impartial evidences" (New York Regents' certificates).—HIGH SCHOOL, WATERTOWN, N. Y.

"I desire our school to be visited, thoroughly examined in all its workings and its facilities for training, by teachers of good scientific schools, and *when approved* to be put upon their lists of accredited schools. Otherwise, examinations."—HIGH SCHOOL, ASHTABULA, O.

"I shall not favor the system at all until we can do more thorough and more uniform work in our secondary schools."—HIGH SCHOOL, HEPPNER, OREG.

"If leading colleges and scientific schools would unite in uniform requirements for admission and admit by certificate from preparatory schools whose courses of study meet their requirements, I think it would be of great advantage to colleges, preparatory schools and students."—ABINGTON FRIENDS' SCHOOL, JENKINTOWN, PA.

"Extend the admission by certificate. By the time our pupils graduate, the worthless are well sifted out. A close connection between the colleges and high schools tends to increase the number of those who go to college."—CENTRAL HIGH SCHOOL, PITTSBURGH, PA.

"For *our* advantage and use, yes. If I were connected with the engineering schools * * * I should oppose it. I am certain that it tends to less thoroughness than an examination."—STATE NORMAL SCHOOL, WEST CHESTER, PA.

"The admission of our pupils on certificate * * * has elevated the standard of work in this school, has caused more graduates

to enter college, and thus far has secured good work in college."—JOHNSTON HIGH SCHOOL, OLNEYVILLE, R. I.

"The system should be widely extended. The present system of examination is vicious, for teachers study the methods of college professors, and prepare their pupils expressly on certain points. This works to the detriment of the pupil and the glory of the teacher."—HIGH SCHOOL, WARREN, R. I.

"Recommend its extension. Students should be prepared for college, not crammed for examination."—WALL & MOONEY'S SCHOOL, FRANKLIN, TENN.

"We recommend an extension of the system of admission by certificate, limited, however, to such schools as have won the right to such entrance by having successfully prepared students for some first-class school of engineering. A right to enter one such university on certificate should entitle such a preparatory school to enter its students in any of them."—WOOLWINE SCHOOL, TULLAHOMA, TENN.

"I recommend the examination method qualified somewhat by the previous work of the pupil as shown by certificate."—GRADED SCHOOL, BENNINGTON, VT.

C. GENERAL STATEMENT OF PRINCIPLES.

Before formulating conclusions or recommendations on the reports thus far analyzed, it will be helpful to direct attention to certain general principles, some of which have been assumed by the Committee, while others form the basis of replies received.

1. In its circulars of inquiry the Committee expressed its opinion that "preparation for scientific or other colleges is an essentially secondary function of the great body of high schools of the country, and that entrance requirements should be, so far as necessary, adapted to the capacity of any high school of thorough methods and high standards."

2. The primary object of entrance examinations, or other requirements, is to determine whether each candidate for admission has attained a certain standard, of development on the one hand, of information on the other, fitting him to undertake the work of the particular college in question.

3. The secondary effect of entrance requirements in particular subjects is a tendency on the part of teacher and candidate to concentration of effort on those subjects required, at the expense—perhaps to the neglect—of others. In particular cases this may even seriously deform the school curriculum. This consideration must not be overlooked in formulating a normal list of requirements.

4. The tendency of all examinations is to stimulate preparatory study, the degree of such stimulation varying widely according to circumstances and requiring, as in case of any other stimulus, very careful control. For such control the colleges must depend in the main on the schools; unless it is exercised, the results of the examination are of relatively slight value. Certain teachers and certain schools are notoriously able to prepare candidates who can pass entrance examinations, but do little afterwards.

5. The entrance examination at its best is a healthful stimulus especially to an indolent candidate; it presents to the schools an external, independent, concrete standard by which their work may be measured to the satisfaction of the ambitious and successful, to the confusion of the unworthy; it enforces upon school committees the need of strengthening weak points.

6. On the other hand, besides the danger noted

under 4, the examination has certain serious defects as a test. Examiner and teacher are separated by a wall with more or less numerous loop-holes, catalogue specifications, former examinations, etc. Too often the examiner's object is merely to select the best of these loop-holes, that is to "coach"—not to educate—his candidate.

It is difficult to proportion the parts of an examination in accordance with the relative importance of the corresponding topics. It is difficult even to make the questions so clear that some applicants shall not totally misunderstand them.

It is difficult to judge applicants fairly—in some cases, even to mark their examinations justly—without personal acquaintance. Some always do themselves more than justice, others less.

Last and most important, while an entrance examination may be an adequate and accurate test of an applicant's knowledge of particular subjects, it is an indirect criterion of general mental capacity on the one hand, and of specific aptitude for the kind of work in view, on the other.

7. In consideration of these defects of the entrance examination system, many colleges substitute admission by certificate, many others attempt to strengthen their weak points by a combination of the two systems.

Some of the advantages of a good certificate system are these:

(a) It requires supervision and examination of the work of the school by the college or by some other central body, thus showing strength or weakness in the work directly.

(b) It gives the certificated school authoritative recognition which, if deserved, it ought to have.

(c) It keeps school and college in touch with each other.

(d) It substitutes for the information test of examinations, the judgment of a teacher to whom the applicant is personally known. A good teacher must generally be a better judge of mental capacity and aptitude than the best examiner.

Familiar difficulties of the certificate system are:

(a) The difficulty of establishing and maintaining—by law, or by college co-operation—the necessary “supervision and examination” of school work.

(b) The extreme diversity of work in different parts of the country and state. The certificate system should tend to remedy this.

(c) The reluctance of college officers to deny or suspend the acceptance of certificates from poor schools.

(d) The reluctance of school officers to deny certification to unfit applicants.

8. The tendency of present diversity is to localize education unduly. It is generally difficult for a candidate to prepare for a college in some other, perhaps distant state, as easily as for one in his own.

D. CONCLUSIONS AND RECOMMENDATIONS.

1. *Uniformity of Requirements.* The committee regards absolute uniformity of requirements as entirely inconsistent with the diversity of educational conditions in different states, and as not in itself desirable. Each community—large or small—must work upward as it best can toward its own ideal. Variation is the basis of evolution.

Needless arbitrary deviations from uniformity in mere details are vexatious and harmful to all concerned and should be removed as soon as possible by co-operation between colleges and schools.

To secure such degree of uniformity as is practicable, the Committee recommends the approval by this Society of a definite list of entrance requirements somewhat as follows:

<i>Mathematics.</i>	<i>Science.</i>
Arithmetic (complete).	Physical Geography.
Algebra, Elementary.	Botany.
" Through Quadratics.	Chemistry.
" Advanced.	Physics.
Geometry, Plane.	
" Solid.	
Trigonometry, Plane.	
<i>Language.</i>	<i>General.</i>
English.	Free Hand Drawing.
French.	United States History.
German.	Some second subject in History.
Latin.	

Table III. shows that this list includes the requirements of nearly all of the colleges. From this list are excluded the scattering odds and ends, Writing, Reading, Partial Arithmetic, Mensuration, Elementary Mechanics, Higher Mathematics, Civil Government, Local Government, Bookkeeping, Elocution, Mental Science, Logic, Economics, Theory of Teaching, Miln's Realm of Nature, Zoölogy, Astronomy, Geology, Mineralogy, Meteorology, Natural History

Biology, Introduction to Science, Etymology, Latin-Elements of English, Spanish and Greek. This diversity has crept in to some extent, no doubt, through the attempt on the part of colleges to meet the varying courses of their contributory schools through a system of options in requirements, and possibly, to make the scientific courses level up to the classical ones without the necessity of imposing the dead languages on the student. But the effect has been to scatter and to produce confusion on the one hand, and to limit each college to its own field of cultivated schools on the other. What some of these subjects are doing as requirements for engineering courses, unless as temporary makeshifts, is not easily comprehended. There is enough within the above list, that so many colleges agree upon, to fully occupy the time of any boy in his four years in the high school, and there is variety enough to give breadth of training. There is work in the five chief lines of Mathematics, Language and Literature, History, Science and Art. Any school course, on the one hand, and any college set of requirements, on the other, ought to include all of these lines.

Again, while the colleges should confine themselves to the above subjects, there is nothing in the list that does not properly fit into the school curriculum. Laboratory work of the right kind in Physics, Chemistry and Botany may be found in comparatively few schools, but it ought to be given in all high schools with four-year courses, for their own sakes, irrespective of the demands of scientific colleges.

Somewhat apart from the other subjects named,

stands Manual Training, including Shop Work and Mechanical Drawing.

It is obviously impossible—even if desirable—to make either of these a requirement for admission to engineering colleges generally. On the other hand, the engineering colleges should be the first to recognize the true value of hand and eye work as a form of education. The committee believes that, so far as practicable, such recognition should be more generally shown by the acceptance of certified work in Manual Training as an optional requirement by institutions accepting any optional subjects. As previously stated there are only two engineering colleges that at present require Manual Training.

2. *What Should be Required.* It is difficult to generalize, to the extent of laying down absolute requirements to which all colleges should conform. Yet, broadly speaking, there exist to-day two grades of engineering colleges whose work lies about one year apart. For the first of these the minimum requirements should include the following subjects :

- Algebra, Advanced.
- Plane and Solid Geometry.
- Physics with Laboratory Work.
- Chemistry with Laboratory Work.
- New England Requirements in English.
- Two years of Foreign Language.
- American History and some additional History.
- Free Hand Drawing.

For the second grade the minimum requirements should include :

Algebra through Quadratics.

Plane Geometry.

Physics.*

English along the line of New England Requirements but less in amount.

One year of Foreign Language.

American History.

Free Hand Drawing.

Below these are colleges, like some of the colleges of Agriculture and Mechanic Arts, that are forced by the necessities of environment or the terms of their foundation to maintain low standards of admission and do in course what other colleges throw into requirements. These should insist on requiring as a minimum:

Arithmetic (complete).

Elementary Algebra.

Plane Geometry.

English along the line of New England Requirements but less in amount.

American History.

Any lower requirements than these bring students into college before they have completed their courses in the lower schools. This works a double injustice, through lessening the force and prestige of the preparatory school and making it necessary for the college to do some of its work.

The differentiation here spoken of is not confined to the requirements, but is naturally apparent in the courses. These gradations in colleges are inevitable. They constitute one of the expressions of the varying

* In the opinion of the committee the Physics should include laboratory work.

conditions of life in the different communities and sections of this broad land. The sooner that this is frankly and freely admitted and acted upon, the better for American education. The older and higher grade colleges should recognize the value and dignity of the work of those that are newer or of lower grade, and on the basis of quality rather than grade. On the other hand, the newer or lower grade colleges ought to recognize that the graduates of the colleges of higher grade are more evenly educated, more broadly cultured and better equipped for professional life than their own, and cease trying to bring about an apparent equality of grade. President S. P. McCrea, of the New Mexico College of Agriculture and Mechanic Arts, writes: "New Western colleges like this will be more concerned in securing advanced standing for their engineering students in the older and high grade institutions, than in attempting to put their work on the same plane without respect to conditions. Can your committee do anything in this direction? If not, can a committee be appointed to deal with this matter?" The same spirit is manifested by correspondents from some other points.

3. *Admission by Certificate.* In the opinion of the Committee, the advantages of the certificate system as already outlined, are fundamental, and its defects are to a great extent temporary and remediable with the general "levelling up" of secondary school work. Here absolute uniformity is not to be thought of. The more general observance of the following principles is of the highest importance.

(a) As the primary essential, personal visitation and inspec-

tion on the part of the college of the school asking a commission.

(b) This commission to be limited as to time and re-issued only after re-inspection, or on full knowledge of the condition of the school.

(c) The reservation of the right of the college to withdraw the commission for cause shown.

(d) Certificates to show in detail the extent of the ground covered and actual time spent in each subject and to contain the personal recommendation of the superintendent or principal.

(e) Students received on certificate to be required to make up any deficiency in preparation that may appear in any certificated subject.

(f) The college to cultivate friendly relations with its accredited schools and to make clear, through publications and conferences, just what its requirements are.

In the application of these principles each college would necessarily work out its own details, and under present conditions be obliged to do its own visiting and inspecting. But there is no reason why the colleges should not co-operate in this matter under suitable restrictions, the commissioning of a school by one, involving its acceptance by others.

4. *Entrance Conditions.* It is fair to assume that colleges making no answer under this head have no regulations. This, with the scattering nature of the replies received, indicates an unsettled state of affairs. The granting of a condition should be largely governed by the merits of each individual case. It should not be used as a breach through which poorly prepared students break into college. The practice sometimes results in an actual lowering of nominal requirements and, when so used, it can be but demoralizing and

perhaps dishonest. The free use of conditions is unfair to the preparatory school, by withdrawing the student before he is through with its course. The acceptance of students on conditions from schools that cannot fully meet the requirements, is unjust to those that do so, while the student may be overloaded and the college deprived of the opportunity to do its best for him.

5. *Execution of Recommendations.* The committee recognizes that in dealing with all of these questions, the independence of each college must be respected, and that the remedy for incidental evils, heretofore resulting from such independence, must be left to the free initiative of such colleges as recognize the gains possible in the direction of uniformity and co-operation.

The committee, therefore, advises that the Society appoint a standing committee on Admission to Engineering Colleges, to be charged with the execution of the recommendations following :

(a) The formulation, with due regard to the interests of non-engineering colleges, of a sufficiently definite outline of work in each of the subjects named on page 166, so that preparation in any subject shall be available for any college requiring that subject. In many subjects this formulation should provide for a minimum and a maximum requirement, *the latter always including the former.* This qualitative uniformity within the above list would be an enormous gain, and should, in the opinion of the committee, meet all legitimate demands of the colleges and all just complaints of the schools. The practicability of such a method has been shown in the work of the Commission of Col-

leges in New England, particularly in English.

(b) That the formulation of requirements by this committee be sent to each engineering college, with an invitation to consider it carefully in issuing its statement of requirements.

(c) That the formulation of principles that should govern admission by certificate, as found on page 170, be also sent to each college for consideration in defining its requirements.

(d) That to all colleges whose requirements correspond with sufficient closeness, the committee recommends co-operation by interchange of evidences of preparation.

(e) That the standing committee report annually to the Society as to changes in requirements for admission to engineering colleges.

Distribution of this Report. The committee further recommends that a copy of this report be sent to all schools and colleges from which information has been received.

Respectfully submitted,

F. O. MARVIN,
MANSFIELD MERRIMAN,
J. P. JACKSON,
J. J. FLATHER,
H. W. TYLER.

THE CONSERVATION OF GOVERNMENT ENERGY THROUGH EDUCATION AND RESEARCH.

BY C. W. HALL,

Dean of College of Engineering, Metallurgy and Mechanic Arts, the University of Minnesota, Minneapolis, Minn.

The State has the right to educate her citizens. No matter in what social sphere they move or what occupation engages them, whether they live in the country or inhabit a city, the State can command all her citizens to acquire an education. In this country, since the people are the government, the proposition becomes: the people have the right to educate themselves. Considering education from the standpoint of the State, it is asserted, "The State must educate because intelligence is essential to the existence of the State."

This proposition may be unsatisfactory until the term *intelligence* is defined. The schoolmaster is not necessary in order to rear a sturdy and intelligent yeomanry. The history of early New England refutes such a proposition; Virginia during her early years is another refutation; Pennsylvania another. Again, there may be a great and fundamental difference of opinion as to what the elements of intelligence are and whether they are to be gleaned from the reading book, the catechism or the manual of arms.

Intelligence, after all, means merely some kind of intelligence, and the kind stands as the measure of the idea in the mind contemplating it. There are persons who would stoutly maintain that the State ought not to exist. Such persons have no weight of influence in

the Anglo-Saxon world. So it is time to advance beyond that position and take a bolder and stronger one based on the following three propositions:

1. Education must be public because culture is the chief and paramount business and interest of civilized men.
2. The education of the whole people is so great and costly an undertaking that private resources alone cannot compass it.
3. The agencies to be employed are so vast and multifarious that they can be organized only by the supreme authority.

On these propositions the whole question is removed from the police station to the forum of statesmanship. The education of the people has been a prominent and growing idea in this country from the organization of the earliest colonial governments. Common schools have been built up and uninterruptedly sustained, not as something for the masses, elementary, but as schools where every citizen in common with his fellows could have free and full opportunity to make as much of himself as his capacity and capability would allow. Under the American conception, the State is constituted of the individual I's within it. The citizen can say: "Since I am of the State it is my right as a citizen to receive and work into my fibre all the State can give, because the State has a right to me; to my goods, my service, and, if need be, to my life itself. If my highest service, the sacrifice of life, be required, I ought to make that service of the highest possible value."

With all the increasing complexities of modern life there is a steadily advancing standard of equipment

required of every man designing to fill any position of official responsibility and trust. The brilliant practitioners of one hundred years ago would find themselves sadly behind, among the regiments of average physicians of to-day; the foremost lawyers of that day would find themselves quite unable to protect their clients in the present decade. It is so with every other field of State service; hence the opinion is inevitable that it is the State's duty to qualify its citizens to discharge the duties of high citizenship, resting assured that those duties will have no limit short of the necessity of the State itself.

This position is not a new one. It is simply the advanced ground on which educators are now standing. It has been reached under the simple laws of development which we find rooted in the district school system of the continent. There are seen, as one looks along the steps of progress since schools were established by the early colonists, three stages of advance; they may be called the three educational ideals:

1. The Colonial ideal. Under this ideal learning was a sacred trust to be administered for the highest interests of God and man; hence the whole force of education was expended on the support of religion and the moral education of society.

2. The Federal ideal. In the words of the Ordinance of 1787, "religion, morality and knowledge being necessary to good government and the happiness of mankind, schools and the means of education should forever be encouraged."

3. The Economic ideal. This ideal is formulated in the now immortal Morrill bill of 1862 which ex-

plicitly directs that certain moneys shall be set aside, whose interest shall be appropriated to the endowment, support and maintenance of colleges "in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

4. Shall we not see in the closing of the present century at least the shadow of another ideal, the fourth of the nation's history, *the defensive*, in which the proposition becomes clear in government policy that the most perfect national defense lies in man's most complete control over the natural forces and material resources of the continent?

A survey of the governmental policy which has been formulated in the light of these ideals, makes it clear that no nation has yet had so large views touching the relations of scientific knowledge to good citizenship as has the United States; no other government has laid before its people such a range of information bearing on the present wealth and the possibilities of their inheritance as has this; no line of statesmen has shown such an intelligent appreciation of the essential constituents of civilization as has the line which from Jefferson to the present time has guided the destinies of the western hemisphere.

Environment means much: sometimes, indeed, it means everything. This government would never have been organized had the colonies been situated on the eastern hemisphere. This people would have expended its energies in the world-wide and world-long activity of self preservation. Invasion and defense would have been its constant occupation. The At-

lantic has proved a veritable wall of defense; behind it the energies of a nation have been given full and free play among the arts of peace. The march across the continent has been to the music of dinner-horn and wheel instead of fife and drum. What a vast difference can be seen when that possible condition is compared with the existing one; had the nation been beset by enemies it must have developed in the art of war, arsenals and armories would then show the results of intellectual application and growth. As it is, workshops, farms, laboratories and homes display a wealth of results in the lines of peace. Farms are dukedoms; workshops are museums in which are displayed the evidences of capacity and skill never before attained in the history of mankind.

Self-defense is a duty and a necessity. Under her geographical situation the opportunity is open to the United States to build up a defense in a new way. Strengthen the peace efficiency of the nation. Build up the internal forces. Educate the young and thus make high and strong the intelligence of the whole people. Encourage high education and thus gather an army of generals of work in all the lines where knowledge is applied to the control of environment. Support liberally the endowment of research and thus not only encourage, but push investigation into every field of human knowledge. Strengthen the nation, through giving it a knowledge of its own domain and a control over the natural forces and phenomena that encompass it and are contained therein. The intellect is the seat of power. A well-trained mind is strong; a nation of well trained minds is strong in the

first elements of strength. Let "millions for defense" be the motto—millions to be put into strengthening the schools, training experts and pushing into fields of research. In this way the two great ends of government can be attained; namely, the comfort and protection of its people and the perpetuation of its institutions. A strong government dwells in peace; a weak one is subject to many attacks.

Thus I would urge the argument of self-defense, Let education and research be not only encouraged, but insisted upon. That these defenses may be developed, let the government appropriate funds to carry them along, both in lines already recognized and in others which just as closely as agriculture, geology and topography, touch upon the lines of defense which the nation, for its self-protection, must construct. Millions of dollars are saved the country through the isolated situation of the western hemisphere, as can be seen when the budget of England, France or Germany is taken as the measure of expense. These countries expend upon their land armaments tens of millions to our millions; millions more are expended upon defenses by the sea.

Two questions arise :

1. To what extent should education be compulsory, or even permitted at the expense of the State?
2. Along what lines should government encourage research?

Answering the first question, the high school is the people's college. Make it the ideal institution for all those struggling below it. It is higher in its work and broader in its aims than the college of

mid-century years. It is rapidly advancing. It has within itself all the elements necessary for educating into intelligent citizenship the whole people of the land. Its curriculum is broad ; it therein meets the demand for diverse tastes and aptitudes ; young people can secure equally efficient training, whether they desire to dig into classic lore, mathematical physics or manual training.

In the second place, considering research work as a step in advance of that education developed in colleges and high schools, it seems that as an offensive-defensive measure no limit can be drawn to it. Investigation of the scientific and economic questions involved in the production and utilization of raw materials; the development and application of water-power, steam and electricity; the improvement of roads; the perfection of steam engineering; the construction of naval engines of various types ; the equipment of the army with perfect enginery of war ; the grappling with architectural and structural problems of high character —these and many other lines of patient and extensive research would be proper fields for investigation.

The United States for the past hundred years has yielded a lavish supply of material and enormous financial resources. Both of these have been used generously in maintaining education wherever a need was pointed out. Times and conditions are changing. It now takes one-half billion dollars annually to do the government's business. Such an amount is not easily obtained. To secure it becomes harder and more trying each year. Every million counts in the footing. Every measure supported by the government

must be entrenched in the interests of the whole people. It must be a necessary factor of good government rather than regarded as a good thing in its way. In the past Congress has followed four different plans in distributing aid to the states for schools and other institutions of learning as summarized by Chancellor Fulton:

1. "The aid granted to the states for common schools was in the form of land located in the states, and the amounts granted to the several states was proportioned to area of states.

2. The grants of land to the states for seminaries and universities were of lands located in the several states and varying in amount not according to any definite policy, from 2 townships to each state to 4 townships to each state.

3. The grants for agricultural colleges under the Act of July 2, 1862, was proportioned to the population of the states as indicated by their representation in both Houses of Congress, being an amount equal to 30,000 acres for each senator and representative from each state in Congress, every state sharing in this distribution.

4. Under Act of August 30, 1890, an equal sum, now amounting to \$20,000, is proportioned to each state out of the proceeds of the sales of public lands for the use of the agricultural and mechanical colleges of the states."

There is a loud and strong call upon Congress to increase the number of educational institutions supported wholly or in part by the government. During the last session of the present Congress not less than

five distinct propositions were under consideration ; to increase the efficiency of the navy ; to establish engineering experiment stations ; to aid schools of mines ; to make an equitable adjustment of grants of lands for seminaries of learning or universities ; and to found a national university. All these are worthy objects. Assuming they are devoid of all possibilities of abuse and extravagance, everyone interested in high education could conscientiously and unreservedly support them all. He could encourage and help maintain a broad and comprehensive policy of support to education on the part of the central government, a policy broad enough to include within its range every line of education and research capable of adding to men's grasp of affairs and control over forces and phenomena. It should be a policy aiming at all times to meet the needs of both army and navy, for therein lie the beginning and the outward forms of defense, and the demands of commerce in its competition with all the world ; the solution of the perplexing problems presented by transportation on land and sea ; the development of the whole water-power of the country ; the long distance transmission of power ; experimentation in the various lines of scientific work ; the general diffusion of knowledge ; the forming of a national university—for all these activities must receive encouragement and support. To maintain and carry forward in a constantly accelerating ratio such a plan of development and intelligent defense, the government must be possessed of large resources and a settled policy. Both are essential to successful work. Resources are not so easily commanded

now as formerly. All sources must be guarded and everything realized must be carefully husbanded. That any broad and reasonable policy can be a settled one, no one will doubt. The National Museum is a stable enterprise; so, too, is the Coast and Geodetic Survey, which was organized ninety years ago for purely scientific work, for a definite and practical end. This work has broadened its scope and increased its usefulness with each succeeding decade. It is proposed that the amount expended each year by the government in support of research work along the lines of applied science should be small. Compare, if you please, the original cost of a college and a battleship; place side by side the annual expenditure upon one floating fortress and the yearly bills of a first-class technical school; consider how many schools of high standard can be supported at the cost of a single regiment of the army. My plea is not that no more battleships be built or regiments recruited; we need them both. But I do urge that, with every such ship put in commission or regiment mustered in, a fair amount be devoted to high education and research. Let it be known that not only along the two lines of defense that have come down to us from prehistoric times and barbaric conditions shall we protect ourselves, but that there is a third and still stronger line of defense builded in these modern days. The United States stands behind that defense, and is thereby making its position impregnable. Nature has been lavish in this part of the world. Almost every material resource and every force and phenomenon of nature are here afforded for the development of the highest character

the human race can reach. To attain a high standard requires most carefully matured plans and a well-digested, far-sighted policy of advancement. Ultimate America will not have reached her highest possibilities of national power and intelligence before she shall have become acquainted with every phenomenon of nature, and have come into perfect control of every force that it lies within human faculties to compass. Then when the whole of America, with all its capabilities and natural forces, is under perfect control, will the national defense be complete and the government will have secured that real conservation of energy which it is the duty of government to attain and preserve.

Much has already been done to attain this end. All praise to those who with loyalty of spirit and singleness of purpose have devoted themselves to the work. Not alone in the concentration of effort and unity of aim, as the government directs its energies, but also in the expert work which has been done in the interest of public defense and the dissemination of scientific knowledge. A bare allusion to the long list of experiments and their tangible and serviceable results is sufficient to show to all that the successes of the past are evidence of attainment in the future. Thus we may assert that loyalty gives service of the highest type.

How can government conservation be more thoroughly attained? How can all the intellectual activities at the disposal of the government be directed so that duplication and dissipation shall not result while the widest range of investigation, education and research shall be encouraged and promoted. Private munificence cannot compass national needs in educa-

tional ways more than personal sacrifice through voluntary and unremunerated service in local militia regiments can defend against invasion, or the merchant marine can protect against foes by sea.

To secure such unity of effort, three ways present themselves:

1. The establishment of a Department of Education.
2. A re-organization of the present Bureau of Education with an enlargement of its powers and duties.
3. Placing all expenditure for educational institutions and experimental research under one department of the government and the appointment of an advisory board to act in an advisory capacity.

If the reorganization of the present Bureau of Education be decided upon, with the necessary enlargement of its powers and duties, the Commissioner can advise Congress to appropriate wisely.

A Secretary of Education with the powers that pertain to such an officer, would have sufficient authority to call in advisors and thus give the strongest possible arguments and reasons for the support of the several lines of education and research instituted by the government. He could prevent duplication and repetition in the several fields.

An advisory board, to be efficient, must be composed of men of the widest experience, highest character and broadest views. It should be a board representing the varied fields of education and research. The writer knows of no more worthy men to suggest for such a high and responsible position than the following : the Secretary of the Smithsonian Institution, the Commissioner of Education, and the

President of the National Academy of Sciences. The stability and steadiness of such an advisory board will be seen when it is considered that the Secretary of the Smithsonian Institution is a permanent officer, the Commissioner of Education is appointed for four years, and the President of the National Academy of Sciences is elected by one of the most intelligent and at the same time conservative bodies in the United States. Were others desired, that the Committee might consist of five or more members, they might be appointed by the President. To this advisory board should be referred all requests for governmental appropriation for the support of existing lines of educational work, scientific and technical lines of research, and all proposals for the extension of such educational work and research into new lines of activity. In this way the whole field can be taken into view, the bearing and possible results of each proposition can be considered, while the Secretary, through whom lies the disbursement of funds, can feel that he has the support of the highest authorities in educational work and that his recommendations to the President and Congress are supported by wisdom and intelligence other than his own.

Of the three propositions the writer would favor the third. What the country needs is government support, not government direction of education and research. Government direction is a bad thing; the thought of it is repulsive to the American spirit, and with it is at all times associated a sense of servility which is repressive to noble sentiment and the freedom of research.

THE HALE ENGINEERING EXPERIMENT STATION BILL.

BY WILLIAM S. ALDRICH.

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This Bill was introduced into the first session of the fifty-fourth Congress; and in the Senate, February 27, 1896, by Hon. Eugene Hale. It proposes the establishment of Experiment Stations for investigations in the applied sciences and engineering industries. These are to be located in each of the several states at that college or university which is the beneficiary of the former national endowment of 1862 and 1890.

Engineering education is to be promoted by such stations affording facilities for undergraduate and post-graduate work in experimental lines; and like facilities are to be accorded accredited engineers for research work.

Developing of the state's natural resources, and promotion of the diverse industries dependent upon these, will follow in much the same manner as the agricultural experiment stations have benefitted these interests.

The publication of bulletins and reports, will detail the commercial tests, engineering researches and scientific investigations of these stations.

Following are the chief arguments already made against the Bill:

1. Engineering is not an experimental science; results once obtained may be applied in a fixed way to all similar cases, with exact formulæ.

2. Engineering experiment is independent of locality, it bears no analogy to agricultural experiment.

3. Government is not called upon to endow engineering experiment to develop the state's resources and industries, to promote technological education for the same considerations of public welfare as were advanced in behalf of the agricultural experiment stations.

4. Too many "engineering" schools are now turning out "mechanics"; the proposed Bill will intensify "rule of thumb" education; it is undesirable, worse than harmful, to fritter away more millions to enable these schools to talk and advertise themselves as "engineering schools."

5. Government should concentrate its endowments; one good engineering laboratory would be worth more than fifty duplicate and unnecessary plants, which would "remain in relatively incompetent hands."

BRIEF OF THE BILL "TO ESTABLISH ENGINEERING EXPERIMENT STATIONS,

In Connection with the Colleges Established in the Several States under the Provisions of an Act Approved July Second, Eighteen Hundred and Sixty-two, and Acts Supplementary Thereto."

Three Bills, essentially the same, providing for such Stations have been introduced into the first session of the 54th Congress and referred to the Committee on Naval Affairs, in the following order:

H. R. 5836, introduced by Hon. D. K. Watson, of Ohio.

H. R. 6452, introduced by Hon. A. G. Dayton, of West Virginia.

S. 2301, introduced by Hon. Eugene Hale, of Maine.

1. *Object.*—To promote scientific investigation, engineering research and experimental testing in the chemical, physical and economic sciences, with reference to their applications in the industries of life.

2. *Relation to the Land Grant Colleges.*—Such Stations are to be established at these federally-endowed educational centres, and placed under the same governing Board. They will afford facilities for instruction in experimental engineering and the post-graduate work of accredited engineers.

3. *Relation to the Government.*—Advisory relations will be established through the Department of the Navy, with which such Stations are to be coördinated. This will be analogous to the relation of the Agricultural Experiment Stations with the Government through the Department of Agriculture.

4. *Experimental Work for the States.*—The determination of the composition and value of their minerals and fuels, constructive and other materials.

Investigation of the scientific and economic questions involved in the utilization of raw materials and of waste products; in the development and the application of water power, steam and electricity, in the production of manufactured products; in the preservation of forests and water powers; and in the improvement of roads.

5. *Supervision of Engineering Inspection.*—The work of these Stations will give scientific aid to the several states in such lines of inspection and of building construction, and in protecting life and property from engineering accidents, casualties and negligence.

6. *Commercial Testing Work of these Stations.*—Such work of experiment and investigation may be carried on for in-

dividuals or manufacturers, upon payment of suitable fees to defray expenses.

Similar Testing Stations are found in connection with many of the German Universities and Technical Schools, of which the parent organization is the Physikalische Technische Reichsanstalt, at Charlottenburg, established in 1887.

7. *Experimental Work for the Government.*—These Stations will prosecute such researches as will secure to the Government the best materials and highest types of motive-power and other machinery and accessories. Due regard will be had to the varying resources, conditions and needs of the respective states in which such work may be carried on to best advantage.

8. *Publication of Bulletins and Reports.*—Each Station will publish bulletins, quarterly or oftener, diffusing its work among the people and giving practical information on engineering science and the state's resources and industrial development. Annual reports are to be rendered to the Secretary of the Navy.

9. *Endowment for Engineering Experiment.*—To establish such Stations, each state and territory is to receive an initial endowment of \$10,000 for the year ending June 30, 1898. An annual increase of \$1,000 is to be made over the preceding year, for fifteen years, after which the annual amount is to be \$25,000.

The accumulation of any surplus at such Station is to be prevented by deducting any unexpended balance from the next succeeding annual appropriation.

Mis-application of the funds debars from subsequent appropriations till the deficit is made good by the State. Funds are not to be applied, directly or indirectly, under any pretext whatever, to any other purpose than that set forth in the Bill.

10. *Relation to Former Federal Endowments.*—This Bill is analogous to the Hatch act. It provides for engineering experiment as that act did for agricultural experiment. It estab-

lishes experiment stations for promoting engineering science and industry as that act similarly provided for the agricultural interests of the several States.

The Hatch act and the present Bill are alike supplementary to the former national grants, of 1862 and 1890. These provide *instruction* in "such branches of learning as are related to agriculture and the mechanic arts * * * with special reference to their applications in the industries of life." The other bills provide for *experimentation* "respecting the principles and applications" of agricultural and engineering science and allied branches of investigation.

Endowment of Colleges

"to teach such branches of learning
as are related to Agriculture and
the Mechanic Arts," * * by the Land Grant bill, of 1862 ;
by the Morrill act, of 1890.

Endowment of Experiment Stations:

"to promote scientific investiga-
tion and experiment respecting the
principles and application."

OF AGRICULTURAL SCIENCE.

(in Agricultural Experiment Stations.)

by the Hatch act, of 1887.

OF ENGINEERING SCIENCE,

(in Engineering Experiment Stations.)

by bills { H.R. 5836
 H.R. 6462 } of
 S. 2301 1896.

DISCUSSION OF PAPERS BY PROFESSORS HALL AND
ALDRICH.

PROFESSOR DEVOLSON WOOD wrote that he considered

this a great scheme, but if the money here proposed to be expended by states could be concentrated in the establishment of one or two high grade Engineering Universities, what a grand scheme it would be. But if this money or a part thereof can be secured in this way, and in no better way, it should not be hindered, it will be money put into education.

PROFESSOR E. A. FUERTES desired to speak first on this question for he knew there were many speakers desiring to attack the Bill, and he did not wish to have them steal his thunder. He was strongly opposed to this Bill because its provisions are such that they will thwart the very purposes which the Bill claims to favor. It has already been stated here that there are more than one hundred engineering colleges in the country, and this is probably four times as many colleges as are needed, since a few schools, strong, well developed and equipped, and especially well manned and located, are abundantly sufficient for the needs of the entire country. We have now more than a hundred colleges, many of them hectic little affairs, under the control, in a large number of cases, of boards of trustees or direction, or of legislative committees, who are unable to understand the meaning of what the profession needs in the way of investigation. Under the propositions of this Bill neither the students nor the colleges will be able to investigate honestly. The investigating side of a college must be entirely separate from the training and drilling side needed by the students. There are, to-day, very few colleges in the country whose professors are competent to investigate, and the intention is to speak most re-

spectfully, and of course excepting the number of professors in our colleges who are very eminent men. These, however, are necessarily very few. To investigate, that is to discover new laws or improve old practices, it is necessary that the investigator should be first, thoroughly acquainted with the field; then, that he should discover what is wanted; that he should command the necessary material equipment; and lastly, that he should know how to get at the results expected.

This Bill proposes to create at least forty-four little schools that it does not guarantee will be properly manned or located; that it does not furnish with enough capital, and therefore such schools will, inevitably, strengthen the greatest of all evils from which the engineering profession is suffering in this country, and in fact, not only the engineering profession, but very largely many educational interests: namely, the spirit of pretense based upon the thinnest smattering. What we really need is a few very highly endowed, superior colleges, to lead on others to better work as preparatory schools, and improve the entire gamut of engineering prestige and practice. Why not concentrate the potentiality of this large appropriation at Washington or Chicago, New York and California, to produce the effects required, instead of wasting money upon irresponsible little spots here and there over the United States?

The teaching of engineering, to-day, requires a large and expensive equipment and an expensive method of using it. Such an equipment as the engineering school demands, if used for teaching, should be em-

ployed only to give fundamental instruction in the principles underlying the relations of force to matter, keeping the action of the laboratory hand in hand and parallel with the work done in the lecture and class room, to develop and build up the proper habits of study in the student. The object of such a laboratory in a school is purely to shorten the time of instruction by the adaptation of the short cuts that this method commands over the old methods of descriptions and unprovable statements; and besides placing the student squarely before nature, teach him to study it and acquire the habit of honest observation from which to obtain concrete ideas.

This Bill also contemplates government superintendence or control, a most undemocratic and also inefficient speculation. With a few bright exceptions, apparently growing fewer every day, much of the scientific work of the government is perfunctory, and nowhere more routine-ridden than in that bureau where this Bill places the little State Colleges. Everyone who has followed the work of this kind of government bureaus has seen how even some of the strongest ones have petered out into nothing. There is our National Observatory; since the time of Commodore Sands, when "The Line" took charge of it, it has remained as silent as an oyster. It has now there a few great men, but they cannot produce anything, whilst a few of them have abandoned the sinking ship and are at Johns Hopkins or elsewhere. Whatever little of science is left in many of these bureaus is honeycombed by vanity and efforts at notoriety. There is the Weather Bureau, which has been unable to keep an independent head for a long

time, yet some of its officers are in every newspaper puffing up the work of "The Service," while the thermometers register only the temperature of hot iron roofs and the belching exhaust pipes and chimneys of elevators and restaurants which surround the station in New York and in other large cities. In so far as meteorology is concerned, they might as well carry the thermometer in their vest pockets.

Can anyone fail to see that these forty-four colleges, with forty-four testing machines, forty-four chemical, forty-four physical, forty-four geological, forty-four engineering laboratories, and forty-four times everything else, can but fritter away and waste money, salaries, resources and opportunities? To develop constructive engineering and its progress, the experiments of these little schools will be worthless. Not long ago the whole engineering world was startled by a fiasco in New Jersey, which assumed calamitous dimensions. What was the reason for it? Aside from details not necessary for this purpose, the main fact is that we have not experiments on a scale large enough to be applicable to the questions involved, and without which the country is exposed to incalculable losses. Will fifteen, twenty or twenty-five thousand dollars a year be sufficient to settle this and many other questions, in rivers, harbors, canals, railroads, bridges, etc., demanding proper scientific care? The education of young men should not be and is not at all involved in the reasons for the existence of a large experiment station.

This Bill speaks of the Charlottenburg school, near Berlin, as a pattern, or example, that we should fol-

low. At Charlottenburg, Zurich, and the École des Ponts et Chaussées, what this Bill calls *schools* are only official government laboratories, to which students have rarely access, excepting as onlooking visitors ; and the tests performed are either on account of the public works of those countries or official investigations by the professors, and not as part of their educational systems with undergraduates. At Zurich there is no work requiring a pound of rail, iron or steel, that goes into a bridge, or a cubic foot of masonry that is put up, but what is looked into, analyzed and tested, at the national bureau in which the government has a great deal of pride. It is not under the direction of the adventitious professor, good, bad or indifferent, connected with that or some other school, but its personnel has been chosen with the utmost honesty, and all employees are eminent in their profession. The results of the researches of such an institution as that would be worthy of confidence by all engineers. Will the researches of our little projected schools be recognized as progress made or be accepted ? Not unless the investigator is known ; for such work is not always self-proving. Is there an engineer who will use, in his practice, the statements of people about whom nothing is known, unless it be that there are probabilities of their being incompetent to do the work, by reason of the poverty of their facilities and equipment ? If this government should do as the German, French, Swiss or Italian governments have done, and establish a large, fully equipped station near the shores of each ocean, giving to them the entire sum of the money called for by this Bill, this money would be one of the best in-

vestments made in behalf of our national material wealth; fully as useful to the country as the most important branch of the government; but it should be out of politics, and under conditions not necessary to mention now, for such an undertaking is not contemplated by this Bill. I am opposed to the provisions of this Bill.

PROFESSOR T. C. MENDENHALL said he was much impressed by the very thoughtful and interesting paper to which he listened, and by the very great importance of the paper which was read by abstract and which is open for discussion. There is time to speak of only two or three points that present themselves. He would like to say a word with regard to the functions of the National Academy, to which reference was made in the paper, because it had seemed to him during the last ten years that those functions, if properly developed, would come nearer solving this very important and pressing problem than any other agency that presents itself. The National Academy was organized in the beginning just for this purpose, but it has not, owing to matters to which it is not necessary to refer, entirely satisfied that demand. To a certain extent it has done so. Although the methods of the National Academy in responding to the demands of government for information on scientific and technical matters is probably well known to all, it may be well to say a single word about it. In the history of the Academy, a number of important questions have been referred to that body by the government. It has not undertaken to solve those questions nor to answer them entirely through its own membership. It does

not pretend to do that, but by the appointment of committees it has searched the country over for the men, wherever they may be, who are recognized as being the best exponents of knowledge on the particular subject in hand, and it has sought and utilized their knowledge in the solution of the problems presented. That seems to be on the whole rather an ideal way of distributing important government scientific problems among the scientific and technical constituency of the country. It is perfectly fair and honest in every way. It does not distribute by population ; it does not distribute by wealth ; it does not distribute by organization ; but if any man in ever so small a college, or in ever so obscure a locality, has distinguished himself in his researches, or in his technical studies of a certain subject, the matter is sure to go to him, and that is a reward which of course is encouraging and in the speaker's judgment always fitting. This plan, if properly developed, would do more than anything else that can be suggested to take all of these questions out of the unfortunate political relations in which they are so likely to find themselves when managed as they have been during the past fifty years.

In relation to the Bill which proposes to distribute a certain amount of money, the speaker had not been able to look upon it with favor, he felt sorry to say, although he had made an effort to do so. There was also another measure which had been advocated very extensively during the past few months, which he could not regard with favor, for it seemed to him to have something of the character of an effort to get some people to pull chestnuts out of the fire for the

benefit of other people. He had not been able to look upon that measure with favor for reasons which there was not time to state in full at this meeting ; but the particular reason which may be referred to, is the fact that the speaker's experience in connection with government scientific work is such as to convince him that government direction is most unfavorable and also most expensive. There is no way in which scientific work is done in this country that will compare in expense with that work which is done under the government. There is no possible question with regard to that. These are two very serious objections. In the first place the unfavorable nature of government direction is something that only those who have had to do with it can understand. He would refer particularly to the proposed reference of this matter to the United States Navy Department which he believed to be unfortunate; perhaps nothing more unfortunate could be done in connection with this work than to refer the direction of it all to the United States Navy, assuming that otherwise there were no objections. He had the greatest respect for that department of the government, for its work and for its personnel, and he believed that he accurately expressed the views of many of those best informed, in declaring that the work of the Navy is not related to this sort of thing, and that the management of most of the scientific work which has come thus far under the Navy has been unfortunate. It is a well known fact that the astronomers have for years been endeavoring to release the National Observatory from the control of the Navy Department.

In further reference to the matter of the direction of scientific work by the government he would like to remind his hearers that the routine of government management, what is commonly known and perhaps very properly known as "red tape," finds its most perfect expression in the military branch, as everybody knows. It is very bad in the War Department. It is perhaps even worse in the Navy Department, in spite of efforts that have been made to overcome it. As an illustration, he had a paper at home giving a record of a case of the payment of a single item in a bill of a Navy Yard, a bill for the payment of ice, in which it is shown to have required 746 signatures before the bill could be paid. In another case a friend, a widely known naval officer, stated that once on board ship he found it necessary to order the purchase of a paper of tacks, and that it required 37 signatures before that bill could be paid. These two little incidents were mentioned simply as an index to the enormous amount of labor and expense that might be involved in undertaking scientific work under the direction of the government, setting aside any other objections that may appear. He would not go as far as his friend Professor Fuerst; there is a great deal of good scientific work done by the national government; but the best work that is done by the national government is done by the civilian bureaus of the government, and that it is the best place for scientific work at the present time. It looked to him a little strange that the engineers of the country should show an anxiety to thrust themselves under one of the military branches of the government, when for several years, if their attitude is understood,

they have been trying to free themselves from another. The speaker believed that the civil engineers of the United States have just complaint in the fact that the public works in this country, the best exposition and exponent of civil engineering, and often mechanical engineering, that we have, have always been conducted by military engineers. He had always felt that to be a mistake in policy.

There are, however, objections broader than either of these to this proposition. One or two of those may be referred to briefly. There is a constant tendency in this country towards paternalism. There is a constant struggle between too much paternalism on the one hand and not enough on the other. That, of course, is a struggle which will continue for generations. The speaker's idea, perhaps not a very clear one, was that the government should always do what the people cannot do for themselves so well, or cannot do at all, and that it should never do anything else. That is to say, if when the problem is presented, "Shall the government do this or shall the people do it?" the question should at once be asked, "Can the people do it?" If they can, they should do it. Now, the work of experimental engineering, it would appear, is altogether possible under the direction of forces that are already in existence and already under organization. The speaker would have the engineering experiment work for the government done by the forces and organizations already in existence. He would have the engineers employed by the government, civil and mechanical, educated in the various engineering educational institutions throughout the country. He would not

have them educated at the Naval Academy. He criticised the reform which has been discussed, and to which he had previously referred, by saying that it fails to strike at the root of the whole matter, which is that it is not the business of the Naval Academy at Annapolis to educate mechanical or steam engineers, and as a matter of fact it does not under its present organization educate them half as well as do scores of other institutions throughout the country. He believed that very much better results would be reached in the other way. He felt, therefore, that the proper course is to try to work through some such organization as was proposed by Professor Hall, and which he believed himself was offered by the National Academy properly administered. What is wanted is not a more intimate relation between government direction and scientific work, of which there has been enough to prove it to be often bad, but a more intimate relation between the demands of the government for scientific work and the supplies which can be furnished by the various engineering and scientific colleges of the country. There would thus be an enormous amount of money saved, besides offering an incentive to all men and schools, large and small, all over the United States, to do the best they can.

He ventured to refer in conclusion to a little personal experience in regard to the cost of government work as compared with what may, in comparison, be called private work. It had been his fortune during several years to administer a government bureau in which the expenditures average about five or six hundred thousand dollars per annum. This was administered

under a civilian bureau and, during the most of the time, under as favorable conditions as could be readily secured through government methods. It had been his fortune, also, within the last few months, to have to do with the administration of a similar fund of about six hundred thousand dollars per annum, these sums being devoted to objects not greatly unlike, in the two cases, and it had been of interest to compare the "office" expenses of these two great public works. He believed that the cost of the clerical or "unproductive" part of the government work was at least four or five times as much as that of the other operation. The executive was surrounded in the one case by scores of useless people, generally impossible to get rid of. In the other case, he is glad to say, that if a man does not prove himself to be useful, he can be gotten rid of very soon, and there is no nonsense about it.

The speaker in conclusion repeated that he felt very strongly that before the engineers of the United States commit themselves in favor of any one of these measures that have been offered for the improvement of these conditions they should carefully study what the consequences will be.

PROFESSOR THOMAS GRAY desired to go on record in this discussion against the Bill. He did not think it possible to obtain money under a Bill of this kind, spread it over the country in the way proposed, and accomplish the object which is supposed to be reached by the Bill. If the government wishes to undertake special investigations which private institutions or state institutions are not able to accomplish now, then

it must create an institution with special equipment, so that investigations of that character may be carried out. In many cases such equipment is already in the possession of the government, and if the bureaus which now exist under and in connection with the government were properly administered there would be no necessity for this Bill. The idea of appropriating even a few millions of dollars and dividing that into one hundred or two hundred portions, and attempting to have every one of these institutions make special investigations in addition to attending to its teaching work, is absurd. The state institutions do splendid work as it is. Their duty is to look to the education of the youth of the state, make them capable of carrying out investigations of this character and trust to the engineering profession in some way or other to find out how to meet the large difficulties in the profession.

PROFESSOR W. F. M. Goss said that he thought it evident from the discussion that there was some ground for objection to the Hale Bill. He thought that while Dr. Mendenhall had called attention to one paragraph which was objectionable, there were other paragraphs which needed to be changed or omitted. He cited the fifth paragraph as it appeared in the present form of the Bill as an example of one which should be omitted. He said that the inspection of buildings and the granting of licenses to engineers were matters commonly dealt with by the state or municipal authority, and pointed out that the proposed Station could not deal with them unless the state or municipality were to delegate authority to the Station, and the state would

have nothing to which authority might be delegated until after the proposed Bill had served its purpose by becoming a law.

But these, the speaker urged, were after all merely matters of detail. The real question that had been called up was larger than any Bill, however carefully framed. The Bill represented a movement which seeks to secure congressional aid for engineering research in the several states, and he desired to be known as heartily in sympathy with that movement. He pointed out that it was not the purpose to establish forty-four additional institutions, as had been stated, and said that the passage of the Bill would not result in the addition of even one institution to the list of those already existing. The Bill simply recognized the existence in every state, of institutions created by the general government and supported in part by the operation of United States laws. Many of these institutions are already carrying on scientific investigations which, while limited in scope, are creditable and even meritorious. The purpose of the Bill, as he understood it, was to aid these existing institutions in the work they are already trying to do. By its passage some institutions which are now weak would be strengthened, while others which are already doing good work would have their sphere of usefulness increased. The purpose of the Bill was a worthy one, and the speaker believed that it would ultimately become a law.

PROFESSOR L. S. RANDOLPH said that he could not say that the Bill was unobjectionable. There were a good many things that he did not like about it, but there were one or two points in this Bill which struck

him very favorably. There had been in his professional experience, times when the location of such a laboratory as was proposed, would have been of inestimable value. Located in Florida, without a testing machine, so far as he knew, within a very long distance, when he wanted to know the strength of a certain material it was necessary to send to New York ; and it would have taken so long to send the specimens on and get a reply, as to make it useless when one is expected to go on the witness stand and testify as to the strength of this material. If there is a laboratory within the state, it is easy to go there and see the material tested. He appreciated what Professor Mendenhall had said about government work being expensive, but we fail to realize the expense of the engineering information which we get. He ventured to say that there is scarcely a test or series of experiments made to-day by our laboratories which have not been made either in whole or in part, imperfectly sometimes, often with a great deal of accuracy, but made either in whole or in part over and over again. He had again and again found it necessary to make rough, crude experiments simply to secure results of sufficient accuracy to settle one little problem ; it was impossible for him to do the work with sufficient accuracy to justify publishing results ; simply a rough, crude experiment was made, and that was all. Sometimes, through losing note books, the same experiments were made a second time. He had run across men who had done similar work simply to determine some special point which it was necessary for them to know.

If there was a laboratory available where the man would feel justified in expending perhaps a thousand dollars, the experiment might be completed and the results published and settled for all time. There is a good deal of work of the sort mentioned which is not fully carried out, but which might be if there was an experiment station near at hand where the work could be done. In relation to the locations of these Stations, when this Bill first came up, the speaker bitterly opposed the idea of distributing them over the country. He thought that to be the worst feature of the Bill; but when he came to look at it more fully, he found that in any central location, whether it be Chicago or St. Louis, or Washington, even the short distance from Virginia would prevent its being of any service to him. Chicago would have been entirely too far away; it would not have suited local conditions; one big laboratory there would have been of little or no use except to the engineers in the immediate vicinity of Chicago. In the case of hundreds of little matters that come up for solution, the local laboratory within the state would admit of their being attended to. Another important matter is that there should be more of government supervision of the strength of materials. The agricultural people say that the fertilizer control system has been of inestimable value. They say that it is almost impossible for a man to put on the market an indifferent fertilizer, or a fertilizer which does not come up to the guaranty; and the formula and guaranty must be printed on the bag, and it is impossible for anyone to put on the market an inferior article, because any farmer can take it to the nearest

state chemist and have it analyzed, and if not according to the formula on the bag, a heavy penalty will be imposed. Such a bureau is very valuable.

PROFESSOR G. H. HAMILIN wanted to say that he believed that when the provisions of this bill were carefully investigated there would be a different opinion held by those who are now opposing it, concerning its utility to the engineering profession and to the people generally, and for many reasons, which he would not take the time to rehearse there. But one thing in particular he did wish to speak of. It has been said that government work is very expensive. He was willing to grant that, but said there must be a distinction made between the expense of work which is done directly by the government and that which is detailed to institutions. For five years the speaker had been the treasurer of the Maine State College and had the handling of the funds which came from the Hatch appropriation, and he wanted to testify here that he believed those funds had been as carefully used as the money which belonged to any public or private institution in the country. The speaker believed that the record which the Hatch Station at the Maine State College had made with those funds, in the few years of its existence, would fully corroborate this statement. Every cent of that money had been as carefully expended as any other revenue which the College had received. The workers in the Experiment Station were just as carefully selected, and worked for just as little money, and just as faithfully as those in any other department of the College.

As to whether or not this Bill is in the correct form

there may be opportunity for a difference of opinion. In the opinion of the speaker it is. It has been brought before this society for discussion and, if possible, to be perfected, and not for the purpose of endorsement as has been suggested. The speaker would go on record as very positively in favor of the Bill, as he believed it to be wise in its provisions, and that it should be passed, both in justice to the great mechanical interests of the country, and to the department of mechanic arts in the land grant colleges, as it would incidentally give the same aid and strength to that department as the Hatch Act has given to the department of agriculture in the same institutions. The speaker believed that when the members of this society realized the difficulties under which the engineering department of these colleges labored, they would take hold and help this matter along. The students in these institutions must learn to investigate somewhere. They are unable to go far from home and incur great expense. They can develop a taste for scientific work and those who do develop the taste generally go to some larger institution, where they can more thoroughly perfect their knowledge. The speaker always recommended his best students who could afford it to go, after graduation, to some larger institution where the equipment is more general and the faculty more special for a post-graduate course.

PROFESSOR W. K. HATT said that he agreed with the remarks of Professor Goss on the matter. He did not know that the Bill had in view the general strengthening of the technical schools; it seemed unfortunate that so much stress had been put on the idea of re-

search. He would not go so far as to say that no research work of any value is done by students in engineering colleges. He remembered the publication, by the *Engineering News*, of certain student theses, which had certainly yielded information of value to the engineering profession. Work of this kind would be furthered by the provisions of the Bill. He thought, however, the generally increased efficiency of the small schools was a more important end, and he would welcome any aid in this direction, although not in sympathy with the form and provisions of the Bill.

PROFESSOR J. E. OSTRANDER called attention to an objection in the abstract of the paper to the effect that engineering experiment is independent of locality. This point had not been touched upon by anybody else, and he would like to call the attention of the members to the fact that there are a number of experiments which are necessarily made in the locality where they are to be used. In the first place, in the Northwest, where he happened to be located at present, there were no testing machines so far as he knew, except those of the Northern Pacific Railroad which had made some tests on Oregon fir. As soon as those tests became known, the value of Oregon fir increased rapidly on the market. It had a sale in places where there was no market for it before. Those tests might have been made at a great distance, but it would have been necessary to ship the timber a thousand miles at least, had not the Northern Pacific had a laboratory. Experiments on the evaporation of water made in one state are of little value in another. It is necessary to have money to conduct these experiments. Experi-

ments ought to be made in certain places on the reduction of certain kinds of ores. Different kinds of ores need different treatment. Without money to experiment on the treatment of an ore it might be pronounced unprofitable to produce it, while if experiments were made a profitable method might be found. These are a few instances where it seems quite important to have an experiment station.

PROFESSOR W. T. MAGRUDER said that while some of the speakers had been on their feet he had carefully gone over the whole Bill, and that he wished to call attention to several statements of the Bill which he thought would convince several of the gentlemen who had spoken that they had misunderstood the Bill. After reading every statement in the Bill where the words "Secretary of the Navy" occur, it would seem to be the case that the sole duty of the Secretary of the Navy is advisory, so far as this bill is concerned, and the function of the Navy Department is to co-operate and to assist the land grant colleges in doing a certain kind of work. What is that work? To establish engineering experiment stations.

Professor Goss has already called attention to the way in which this money is to be appropriated, namely: "out of any money in the Treasury not otherwise appropriated." The speaker wished further to call attention to section 11 of the Bill which provides: "That a director for each engineering experiment station organized under this Act shall be appointed and his duties shall be prescribed by the governing board of the college with which such station shall be established." So that if a person is appointed director of any engi-

neering experiment station he will be appointed by the board of trustees on nomination of the President of the College. The Secretary of the Navy will have nothing whatsoever to do with it. The director will have to report to the Secretary of the Navy only to the effect that he has done certain work during the year and that he forwards the results. From a careful reading of the Bill it would seem as if the sending of this report to the Secretary of the Navy was the only thing necessary for him to do so far as the Navy Department is concerned.

There is need for a bill of that kind. All bills passed by governments are like all human beings, imperfect. This one may not be the very best bill that somebody might devise. At any rate, is it not a step in the right direction? Is not money needed in order to develop engineering research, in order that accidents shall not occur from ignorance of the proper conditions, and in order that the work of the state may be advanced; money, for investigations which cannot be obtained from state governments? Take, for example, a very homely case. How much is known about the strength in compression of the building stones of New York State? Someone says, "Why, yes, experiments were made with two-inch cubes of such and such stones in such a testing machine, and they stood so many pounds;" but who can tell how much stress should be put upon a lintel, or the proper factor of safety to be used in the case of a stone pier, column or wall? It has already been discovered in New York City that some of the so-called "facts" resulting from experiments made by some of the most able experimenters of this coun-

try are utterly unreliable, owing to the size of the specimens tested; that instead of granite, for example, being the very best stone for use in New York City for certain purposes, the rock taken from Manhattan Island is vastly superior in strength. If at the experiment station in New York State, a series of experiments should be made covering the entire state, so as to determine the strength of the building stones of New York State, not only in two-inch cubes, but in columns from ten feet up to eighteen or twenty feet in height, and of suitable sizes, the data obtained would certainly surprise very many present and be of inestimable value and benefit to the building and engineering world. This work being of interstate importance should be done at the expense of the general government and in the respective states.

PROFESSOR C. W. HALL wished to say a few words, partly in defense of his own position and partly in support of Professor Aldrich's "brief" and summary of the Hale Engineering Experiment Station Bill.

In considering the situation occupied by American institutions, it seems that the present year of the present decade is a time for educators to determine what the situation really is. The government is finding it more and more difficult to secure resources for its ordinary expenditures. Again, support of education, using education in its broad sense, is becoming the settled policy of the government. There are five propositions before the present Congress, as the speaker stated in his paper, providing for the use of national resources to educate the people and thus in the noblest way strengthen the nation. Enough is known of the

methods used in securing legislation to make it clear that the advocates of each measure will not take pains to inform legislators of the merits of any bill other than their own. All the measures named are worthy of support.

The speaker was heartily in favor of engineering experiment stations. Yet the broader question is, "What is to be done?" Educators realize that they cannot get everything. One duty devolving upon them is to inform those concerned in the administration of affairs somewhat as to the relations of government to education. If educators do not know what the country wants in the line of educational support, who in this broad land does know? The discussion engaged in this morning is timely; the speaker was glad to have presented the objections which several speakers have brought forward. They have little weight against the main proposition, viz.: government support of high education and national defense, and are urged simply against some particular method of giving that support. The presentation of these points may make it possible to perfect a more economic method than has yet been adopted. It has been said in the discussion that the plans proposed are wasteful; all plans of distributing money in any part of the country are wasteful on the standard of individual economy. There is no district school but has had its experience with a poor teacher, unsatisfactory apparatus, or the building of its school house, and has felt that large sums of money have been wasted. Every college has had its weak department. Indeed, there is no institution but has in some case applied its funds in a way that later

judgment would have shown impracticable. Unfortunately it did not have that later judgment as a basis of action. In other words, conditions change from year to year and experience as well as education costs money. Under the Morrill Land Grant Bill, money has been distributed; it has been found that some states realized very little for several times 30,000 acres received ; other states, through the far-sighted statesmanship of one or two citizens, have attained to a munificent endowment. New York is a conspicuous example of the advantages reaped from that grant, conferred before it was known what was the best thing to do, when the country was ignorant as to its best needs in education. With the combined experience and knowledge which has been added in a third of a century of conscientious work, educators should be able to advise the government. The advice given should be along the line of government support rather than government direction. Government direction in this matter is an entirely undesirable thing and not to be countenanced here. Government aid for the many institutions is an essential thing if they are to be built up along the line of national strength and defense.

THE SEMINAR METHOD OF INSTRUCTION AS APPLIED TO ENGINEERING SUBJECTS.

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Instruction in the subjects required in an engineering course is commonly given either by lectures or through the study of text-books, the latter being often supplemented and explained by lectures. There has already been some discussion before the Society concerning the relative advantages of these methods, each of which has its advocates and both of which are probably employed to some extent by most teachers.

The most common practice seems to be to give mathematical subjects requiring close consecutive treatment from a text-book, and subjects of a descriptive nature by lectures, using very generally a brief text as an outline. This, in most cases, seems a satisfactory arrangement, but methods must always be adapted to the teacher; that with which one succeeds is a failure in the hands of another, and each man must work out a method to suit himself and his work.

The Seminar Method, unlike those already mentioned, seems to have been used only to a very limited extent for engineering subjects, although it is commonly employed for graduate work and frequently in the more advanced undergraduate courses in literature and general science.

This method consists essentially in teaching a sub-

ject through the independent research of the student in the library. There are many ways in which such work may be conducted, and the method is susceptible of any number of modifications which may seem necessary in order to adapt it to particular circumstances.

The subject to be studied may, for instance, be divided into a number of headings, to each of which every student is required to give a certain minimum amount of study, for the purpose of securing a proper distribution of work, as well as to afford a general view of the subject and a proper conception of the relations between the various divisions.

A division of the subject may also be assigned to each student as a theme upon which to prepare a paper for presentation before the class, the other members of which are expected to discuss the paper or to answer such questions in relation to the matter under consideration as may be raised by the teacher. Or, in place of having papers prepared, dates may be set for the discussion of the various divisions of the subject, any member of the class being liable to be called upon to give the information he may have gathered or to answer questions.

In such work the student should be required to take notes upon all his reading and submit them for examination. These should not be lengthy abstracts, but brief notes, neatly and systematically arranged according to subject, such as may advantageously be used in the thorough investigation of a subject, and admitting of ready reference and indefinite extension.

The arrangement of the work and the amount of assistance to be given the student in his preparation

are, of course, matters to be judged by the teacher in each instance. It may seem advisable to furnish a brief syllabus, giving, under each heading into which the general subject is divided, a synopsis of points to be investigated or questions to be answered; or, lectures may be given upon the general subject, in order to present more systematically its elementary relations and preserve its continuity, leaving only certain sections to be more fully investigated through the research of the student.

For the purpose of aiding the student in his work, references may be given to books or periodicals to a limited extent, but instruction should also be given him as to the best methods of looking things up for himself. Practice in the use of the various indices, and learning where and how to find what he needs, should be considered of more importance than the number of facts gleaned from the reading. Advice and help should always be freely given the student, that he may work to good purpose and not be obliged to grope in the dark; but the aid should be so rendered as to require the student to do the work for himself.

It would be useless to enter into a discussion concerning the details of arrangement of a seminar course or the variations to which the method is subject. The conduct of the work must be varied in each instance according to the capabilities of the teacher, the nature of the subject, and the number and training of the students in the class.

The object in presenting this paper to the Society is simply to invite attention to the desirability of intro-

ducing into engineering courses some means for making the student better acquainted with the range and use of engineering literature and to suggest that the adaptation of the seminar method to some of the more advanced studies of the course might be of very great advantage as conducing to this end.

In many engineering schools efforts are made to interest the students in the study of engineering literature, various methods being used for that purpose. References are given in lectures to matters of general or historic interest; the reading of current periodicals is required or papers are prepared by the students upon assigned topics. It is undoubtedly true, however, that a large proportion of those who graduate from engineering courses have very little idea of any professional literature beyond the text-books they have used, and perhaps a magazine or newspaper they have become accustomed to read. Looking up references given in lectures and the reading of current periodicals are both of value in stimulating a taste for general reading, but they have not the same office as the systematic study of literature relating to a single subject. The preparation of papers for the engineering societies which exist in most colleges, and the thesis work commonly required for graduation, both ordinarily involve some research upon the part of the student and tend to stimulate a taste for independent investigation; but, as such work is not commonly under the immediate direction of the teacher, the student has not the benefit of that careful guidance which may be given in a definitely projected course, and is not held to the same accountability for the character of his work.

In considering the introduction of seminar methods it is at once clear that they can have but very limited application in an undergraduate engineering course. Evidently a method such as that outlined above would not be applicable to those fundamental subjects which form the base of an engineering education and which constitute the major portion of the work of an engineering course. These require logical and orderly development as well as the use of methods by which they may be given briefly and concisely.

The seminar methods should be limited to a few of the subjects near the end of the course, preferably those which may properly be called "professional subjects."

These methods also are not well suited to a very brief course. It requires more time for the student to obtain the same knowledge of the subject treated than if it be given by lectures or from a single text, while in order to accomplish good results sufficient time should be available to go quite fully into the subjects considered. They may therefore be applied with advantage to certain lines of professional work into which the student may be permitted to go more extensively than is possible in others. It is still more an advantage if the work so treated may be to a certain extent optional, and all students not necessarily held to the same work.

It matters very little what the particular line of work may be, provided the student be required to go somewhat fully into an examination of the fragmentary literature of the subject chosen, and to put his results into a shape available for use. Having investigated one subject he will know better how to proceed when under the necessity of investigating another.

The object, as already stated, should not be primarily to communicate knowledge of a special subject, although the information obtained must be of value, but rather to give an idea of the extent and nature of the literature of engineering, and to cultivate, so far as may be, the ability to use it.

DISCUSSION.

PROFESSOR DE VOLSON WOOD wrote that he thought the suggestions in this paper to be worthy of serious consideration. The success of the method depends upon "environment." He had been able to do but little, very little, with it with large classes, except in the preparation of theses. There are two courses in the Institute which may be called "Seminar." One is in a supplementary term of four weeks in which certain classes do shop work, make tests of all kinds of machines, take and reduce notes and the like. The class is divided into many sections that there may be only a few students in a section; and temporary instructors, most of whom are employed for the four weeks, take charge of special subjects. One may have charge of refrigeration, another hot-air engines, and so on. During this time there are no recitations, but at its close there is an examination. This is considered an exceedingly valuable part of the course. It will be seen that the plan is similar to that described in the paper by Professor Marvin in Civil Engineering. Our other seminar is the preparation of a thesis for which at least eight weeks are given at the end of the senior year. The student is put upon his own resources, but upon any new or difficult point

is free to consult with the professors. When completed it is reviewed by two or more professors, and notes made in regard to the exhibition of knowledge, clearness of descriptive matter and neatness of execution, and if not satisfactory it must be revised. When satisfactory it is typewritten and a copy left with the Librarian. It is quite possible that a seminar following more closely the method of Professor Spalding would be more profitable in many cases than the thesis as described above, but in his own case the method used by him had, he thought, given a better average result up to the present time than any other plan would be likely to.

PROFESSOR F. E. TURNEAURE wrote that he considered the seminary in engineering education one of the most valuable aids at our command. Education means the ability to investigate and to draw correct conclusions, and this implies, first, the ability to study and reason, and second, practice in getting and using information and therefore, as well, a knowledge of the sources of information. Lectures and text-books are necessary in teaching the tools for use in investigation and they may furnish a considerable amount of valuable information, but after a knowledge of these tools is acquired, the seminary method, whether called by this name or not, is essential to the acquirement of power and independence. Engineering graduates are often needlessly handicapped simply from lack of knowledge of the sources of information, and this lack may reduce the efficiency of their work for several years. This certainly can be corrected by even a moderate amount of seminary work. The use of as-

signed readings will be of some value in giving the student familiarity with the literature of a subject, but it falls far short of the seminary in other respects. He believed the seminary method could be readily used not only for minor subjects which are treated fully, but also for portions of more extensive subjects. In his own experience he had used this method very largely in the teaching of water supply and of sanitary engineering and found that, without exception, the students felt that they got a good deal from the work. In these subjects it has been found best to use the method as supplementary to lectures, giving perhaps one third of the time to the seminary. There is ample opportunity for assigning certain comparatively independent portions a few weeks in advance. These subjects are then as thoroughly investigated as possible, carefully written up, read and discussed in class in regular order. Where a certain order of treatment is essential, and where each part depends on the part immediately preceding, it would be impossible to do this. Papers can be prepared, however, and handed in for examination. The presentation of the papers before the class is a valuable feature, as it adds interest to the work and responsibility to the one preparing the paper. After having been read and discussed, papers should be carefully revised and corrected with the aid of the instructor and, if practicable, printed for the use of the students. While the members of the class are good listeners and usually much interested in the paper and discussion, they do not as a rule carry much away with them in the shape of good notes, and as a result would not get a very clear idea

of the subject as a whole if given entirely by this method. This is indeed the serious drawback to its application. Printed notes would obviate the difficulty and besides give valuable practice in revision and abstraction. In comparatively brief subjects this can be done by the aid of typewriter and mimeograph, with moderate cost; supplemented by such notes the seminar method would be the very best possible way of presenting many professional subjects. In other cases it should be carried out as far as possible, consistent with the acquirement of a fair knowledge of the subject as a whole, for the student doing the work is gaining in this way faster than he can in any other. Knowledge of details of the entire subject is not important. What is required of all students is a knowledge of fundamentals and the bearing of each part on the whole; habits of query and investigation will unlock the details when they are needed. Professional subjects can be made as valuable for training as such subjects as History or Economics, and this fact alone justifies the study of such subjects to a very considerable extent.

PROFESSOR ROBERT FLETCHER found the following, which partakes of the seminar method, to work fairly well: The main subdivisions of a course of civil engineering may be drawn out in the form of schedules or programs; the principle references to illustrations, descriptions, to articles of any sort which are important and valuable as bearing upon that topic, may be affixed to the various sections and subdivisions of this topic, and put into the hands of the student. These simply direct his study of the subject. A student is

all at sea when he is first left to himself to work up a subject. Indexes may be put into his hands, but it is possible that he may fail to get at that which is most important. If the instructor has already arranged from his own reading and experience some of the most valuable references, and puts them into their proper connection with the program of the course of study, the student has something at hand as a guide or model which serves to start him right; he learns the uses of indexes, and gets some idea of the sources of information and, of course, then, from this beginning he can proceed, as far as opportunity will permit, for himself.

PROFESSOR STORM BULL agreed most heartily with Professor Spalding in this matter. He desired, however, to point out one danger which sometimes might destroy the usefulness of the method. In a comparatively large class there will always be students who either dislike the study or who are naturally indolent; these students will not work up the topic assigned to them until a short time before it is to be presented to the class, and because of the size of the class there may, perhaps, be but one assignment for each term or semester. The consequence will be that the students in question will do but very little work themselves, and the information received by the remainder of the class through the presentation of the topics will be of very little value. If the class is small the students may be called on so frequently that this will not occur, and it was, therefore, the opinion of the speaker that the use of the method should be limited to such classes. He would, in conclusion, state as his opinion

that the method should not be used simply for the gaining of knowledge, but in part for learning to investigate a subject rather than for the subjects themselves.

PROFESSOR C. F. ALLEN said that it was understood, of course, by all, that the same methods are not applicable in small classes as in large classes, yet something can be done with this method in large classes, although it can be used more fully in small classes. A modification of this method had been used by him to a slight extent in a class which is neither very large nor very small. The students go so far as to prepare certain subjects upon which the professor has been accustomed to lecture, with the purpose and the result that the student lectures to the class upon the subject assigned. This serves several good ends. The student, after he becomes a practicing engineer, will be called upon to make a report to some body of men, and the fact that he has previously been upon his feet for a similar purpose will be of value to him. In preparing his lecture he will naturally follow something of the methods of his professor. The exercise should not be carried very far, but is a good one for use in a limited way.

PROFESSOR W. K. HATT thought that Professor Spalding quite properly pointed out that the use of the method was limited to certain subjects, and the speaker had noticed the success of the application of that method. It is a fact also that the student in preparing his paper for the seminary gets very much interested in that and is apt to neglect his other work. Because the student must have had his preliminary

training in mathematics and similar subjects, the speaker thought the seminar method should be limited to the senior year and to certain subjects.

PROFESSOR L. S. RANDOLPH found this subject to be one in which he had been interested for a year or two and he had been reaching out towards it gradually. His attention was first directed to it by a description of the use of this seminar method in literary colleges and he had tried it with one of his post-graduate class. The speaker remembers the first time he assigned a topic to one of them. The instructions were to design a turbine wheel and make the general drawings. The work done was surprising. When asked how he got along, the man said he did not know there was so much to a turbine wheel before. When a student works out a subject, passing from one step to another, he gets the relation of the different parts in a way impossible either in a lecture course or by means of a recitation. A student may drop a recitation; he may study one portion of a recitation better than another; but if he has to work out a subject so that one step depends on the other he will get the idea in a fashion impossible by any other method. When he leaves the college and goes out into practical life he has to take the subject up in that way and handle it, and while it is not necessary always to call it a seminar method, or anything of that kind, that principle is of the utmost value in teaching. Once or twice the speaker had gone so far as to plan out a course in which the whole work was to be handled by problems, not only simple problems, but also complicated ones, involving a number of simpler ones, so arranged as to

lead to the final result. That plan he hopes to try before long. The seminar method, even though we do not have a formal seminary, can be used to very great advantage.

PROFESSOR F. H. CONSTANT believed with the first speaker that the difficulty is for the student to lay hold of the information that he wants. After he leaves college he must get this information entirely by himself. To meet the difficulty some of the professors of the University of Minnesota have organized technical reading classes. Professor Shepardson, who is with us to-day, was the first to adopt this idea. The technical journals are allotted to different members of the class and perused by them. At the end of the week the class meets, under the supervision of the professor in charge, and the different members of the class are called upon for reports of the papers they have read. These reports are extemporaneous in most cases, and card indexes of the important articles are made by each member of the class. This, while not exactly the seminar method which has been spoken of to-day, is a very fair introduction to it. Both methods recognize the fact that there is a great realm of engineering facts, a small part only of which can be imparted to the student while he is in college, and that these same facts form the bone and sinew of his engineering work. They are founded upon experience and after graduation it is quite necessary for him to lay hold of them. So this plan leads the student to read the technical journals to the best advantage; to recognize the important articles as he comes across them; to keep a record of them; to remember them

in a general way so that in time of need he may be able to lay his hands upon them.

PROFESSOR WM. F. M. Goss thought that the general plan outlined would perhaps be applicable under a variety of conditions. He had found that the process described by Professor Spalding gave good results when the laboratory rather than the library is made the basis of the work. Subjects to be investigated in the laboratory are assigned individual students, who, in proper time, prepare a carefully written report which they present to their class as a whole. Such reports usually contain a careful statement of the whole problem assigned, a description of methods employed, and a brief discussion concerning the significance of the result obtained. In the case of senior students in mechanical engineering he found the plan to be profitable both to the individual student and to the class.

PROFESSOR GEORGE D. SHEPARDSON mentioned a method which he had used to some extent in the laboratory—he presumed others had used it in the same way—that is, to give a student a problem and allow him to use his own method for working it out. In that way, of course, the student gets some help from the laboratory manuals, but necessarily searches through more or less of the current literature to find the best methods of covering the ground. After he has outlined the method he proposes to follow, he reports to the professor in charge and is advised whether that is the best method or whether he ought to find a better one.

QUANTITY vs. QUALITY IN SMALLER COLLEGES.

BY ALBERT KINGSBURY,

**Professor of Mechanical Engineering, New Hampshire College of Agriculture
and Mechanic Arts, Durham, N. H.**

The problems confronting the teacher of engineering subjects in the small college seldom admit of complete and permanent solution. This is especially true of the adjustment of those constant antagonists, *Quantity* and *Quality*. What subjects shall we teach? How much time and labor shall we devote to each? Shall we study a small number of subjects thoroughly, or a large number less thoroughly? These questions, which arise in all schools, are probably more difficult for the small college than for the large one.

The reason for the existence of the small college is its accessibility, rather than its efficiency or its economy as an educational factor. It is a local magnetic center, attracting much crude as well as refined metal which could not be moved by the more powerful but distant magnet. But for the existence of the small college, possibly only one out of five of its students might go to college at all. As far, then, as the other four are benefited, there is pure gain to the world, and this, with the greater or less excellence of the training of the five, constitutes the institution's claim for just recognition.

The accessibility of the college involves in general not only that due to its location, but also that due to low expense to the student and, perhaps most of all, to the comparative low requirements for admission. This last factor, though practically essential, while

our educational sources are only remotely co-operative, is largely responsible for the difficulties in meeting the needs of the students admitted. The writer has no wish to enter upon the subject of preparation and entrance requirements in general. The fact stands that there are many technical colleges whose entrance requirements are comparatively low. Consequently the candidates admitted vary greatly in respect of previous education and of natural ability. Among them are some having high talents and excellent training; others with good capabilities but less thorough previous education; still others less favored in both respects.

To meet the needs of these various students the typical small college has a disproportionately small number of instructors, a scanty material equipment, and the absence of funds, which is too common in colleges of all kinds. The professor of engineering, with his one or two assistants, must give instruction in the whole range of the professional studies, and often in some of the associated subjects, and usually there are added to these labors the distractions of much incidental mechanical and clerical work. The course in engineering is less comprehensive than the corresponding course in the larger colleges. It is well within the possible effort of the brighter student; it is too difficult for those of less natural ability and poorer preparation. The impossibility and undesirability of forming all students in one mould is hourly apparent. There is everywhere need of individual attention from the teacher, both for the more advanced student and for his slower classmate, giving to the one additional and

higher work to excite his best effort, and to the other the necessary encouragement in every possible way. And finally, the degree which crowns the four-years' effort of each is, perhaps because of abuse, a symbol of little meaning. It does not indicate in itself the vast differences of attainment beneath it, as between individuals from the same college or between those from different colleges.

To improve these conditions and results several radically different plans have been suggested. Among these plans is that of raising the standard of scholarship as nearly as possible to that of the larger colleges —increasing the entrance requirements and extending the course of study. To the teacher whose ambitions lie in the direction of the higher lines of study this is a most attractive plan. It would naturally demand from him more effort as a student, and possibly less as a teacher; decreasing the number of his students, and retaining those most easily taught. It would enable the teacher to give more individual attention to the student. The students taught under such a plan would undoubtedly be better trained than they would be under the less favorable conditions. Nevertheless, it does not seem that the plan is one to be generally adopted by our smaller colleges. Only a teacher of extraordinary ability could, even with two or three efficient assistants, conduct a course equivalent to that of the larger college, with its corps of specialists and its well-equipped laboratories. Hence the plan could not yield the best results, even for the few students educated under it. Moreover, it would have a most undesirable effect in excluding those students of earn-

est purpose and diligent application who, for any reasons beyond their control, may not be able to follow the course of study laid down. The sympathies of the conscientious teacher are strongly drawn to these students; and he, of all builders, does not wish to refuse any stone which *may* become the "head stone of the corner."

A second plan is that of so arranging the course of instruction as to include a comparatively small number of subjects, giving the students more thorough training in those subjects and leaving for supplementary study at a larger college such subjects as may be studied there to better advantage. The beneficial results to be expected from such a plan would be, first, the thoroughness of training of all the students, and second, the specially good preparation for post-graduate study at a larger college.

The writer believes this second plan to be one not generally practicable and beneficial. In any case in which it might be adopted there would still remain the great differences in ability and preparation of students necessarily in the same classes, unless a high standard of scholarship were required. The students taking post-graduate work would probably be benefited by the plan, but this would be outweighed by disadvantages to the students not taking a course after graduation. It is well established that the most that a college can hope to do is to give its students a good foundation for future development. The writer believes that in the average engineering college that end is best attained by touching all the subjects of chief interest in the professional work anticipated,

even though the time devoted to each be undesirably short, as indeed it is, even in our most advanced institutions. The abstract aim of education can not be said to be best attained by teaching any particular subject in any special proportion. The development of mental power and the formation of habits of study do not depend very closely upon the curriculum, but with most students the probability of good development after leaving college does largely depend upon the curriculum. The foundation training should at least ensure the erection of a fairly good superstructure. A slight knowledge of a subject is vastly more likely to lead to farther study of it than is no knowledge at all. It is the unknown which is uninteresting and *vice versa*. If one knows no letters of the Greek alphabet he is not likely to trace out Greek roots in the English dictionary. The cases are rare in which a student takes up a new study after graduation. If he study at all it is most probably in extension of some subject previously begun in his college work. If he leave college with no laboratory practice and no knowledge of design, though well drilled in applied mechanics, he is not in the best way prepared for development as an engineer. The college course at best is but the skeleton for which the later experience of the engineer furnishes the living, working forces; and it is better that the skeleton be complete, though not of great strength, than that it should be strong while lacking the right arm.

The small college is right in offering a course in engineering, including all the subjects regarded as vital in such a course, even though the facilities for

instruction be less than sufficient. If any general improvement is possible in the work and results it is to be sought in a different direction from either of those already mentioned. Many of the young men entering these colleges may much better be educated through the hand than otherwise, and a suitable course should be offered to them whenever the extension is possible. The college exists not only for the purpose of training students into habits of efficient study, but also for giving them as much experience as possible within the available time. Only the student of the highest mental ability can make the experience of others thoroughly his own—the experience of others as placed before him in the text-book and the lecture room. The less acute mind is more readily trained through its own experience. The functions of the engineer are the highest in all industrial activity. Only a small proportion of men can become well fitted to exercise such functions. A course of study leading to even an initial degree of fitness for engineering work cannot be made such as to be successfully followed by the average student. Such a course is essentially mathematical. The average student acquires some familiarity with higher mathematics only by strenuous effort, in which the real end is lost to sight. In the effort to acquire the tool he does not learn its applicability. The education of a fair share of our students could be better accomplished by courses less advanced than the existing ones, involving less of the higher mathematics, and more education through the hand in the shop and the drawing-room and the laboratory. Such a course

need not be less thoroughly educative than a higher course in engineering, nor would it require less effort on the part of the student than the average college course. Its graduates might be expected to develop into highly skilled mechanics, draftsmen or supervisors of skilled labor more frequently than into creating and controlling engineers. Such courses have already been established in various colleges, but their full value and importance is not yet generally recognized. Their intrinsic value would, in many cases, be enhanced by the greater freedom they would leave to the regular engineering courses. The installation of such courses, in addition to the higher courses in engineering, would, in most small colleges, require some additions to the corps of instructors and to the material equipment; a requirement which, in many cases, would be difficult to meet.

HOW TO DIVIDE SUBJECTS FOR ORIGINAL INVESTIGATION AMONG DIFFERENT COLLEGES.

BY CHARLES H. BENJAMIN,

Professor of Mechanical Engineering, Case School of Applied Science, Cleveland, Ohio.

The thought has frequently occurred to the writer that more would be gained by original investigation if there were more unity of action among engineering colleges. The investigator, in conducting a series of experiments, is hampered by a lack of knowledge of what has already been done, and in fact is uncertain as to whether he is not going over ground already trodden by some other explorer.

The transactions of the various engineering societies and the bulletins issued by some of the larger colleges are great helps, but it is undoubtedly true that the great bulk of what is being done does not find its way into print in a way to benefit the general worker.

With no general system of collaboration, experiments are all the time being duplicated, and while this is not always an evil, it is a waste of time when there is no way of comparing results. There is also such a lack of harmony in the methods of attacking problems in the various engineering laboratories that it is usually difficult to make comparisons at all.

The small colleges and technical schools are perhaps more affected by this lack of system than the larger institutions, since they do not publish results to so large an extent. Still, experiments made at a small college with limited equipment may be as valuable as those made at the larger laboratories. The field for

investigation is so broad, and there are so many things waiting to be found out, that every one may do something. The earnest investigator may find much that is new and valuable with one testing machine or one engine, if he only knows where to look.

The work being done in astronomical observatories may serve as an analogy. In this branch of science each investigator knows what things have been done, what things remain to be done and who is trying to do them. He can then confidently begin work on his particular line of research, with the certainty that he can add something to the sum of human knowledge, and he is not at all hampered by the fact that his telescope has an aperture of only six inches while his neighbor's has one of thirty-six.

The engineering observer, on the other hand, is to a certain extent in the dark as to what his neighbors are doing and as to whether his work will be of any value when completed. He is somewhat discouraged also at the meager equipment he has at his disposal and inclined to think that it is useless for him to attempt original research, when, if he knew just where to begin, he might accomplish just as much in his way as his more highly favored neighbor in his.

It would seem that this Society, by its membership, was particularly well fitted to institute a reform in this direction. Just how this reform should be brought about is a question which can only be settled by a full and frank discussion.

A committee might be appointed by the Society, consisting of members of the various engineering pro-

fessions, such as civil, mechanical, hydraulic and electrical engineering, to consider the subject and report at the next meeting.

This committee might ascertain from each member the equipment at his disposal for engineering research, the amount of time which could be devoted to it and a brief bulletin of recent and prospective investigations. It might become apparent to the committee that the equipment at certain colleges was particularly well adapted for certain lines of research. It might also be seen that work which one member was doing could be well supplemented by the work of certain other members if they could combine their energies and systematize their methods. It would undoubtedly become evident that some well-meaning but poorly informed inquirers were throwing away their time in winnowing old straw.

The committee might properly receive advice from all members who are interested in this subject, especially suggestions as to inviting lines of research and fields where there is need of more workers. The position of the committee or of the Society in this work would be of an advisory character. No member would be obliged to follow their suggestions unless it pleased him to do so, but the mutual advantage of some such an arrangement would be so great that no member would be apt to disregard the advice given.

At this stage of the world's history it is hardly necessary to enlarge on the advantages of harmony and concert of action in any undertaking, and to one who believes that the spirit of scientific investigation is the great motive force of the world's advance-

ment, the importance of using intelligently the time and means at our disposal needs no argument. This paper has been written in the hopes of provoking discussion and not as a full presentment of the subject.

No doubt some will say that this Society has nothing to do with original research. It is not the intention of the writer to propose that scientific papers of this character shall come before the Society, but that this Society, which is made up of teachers from every branch of engineering, shall endeavor to organize its membership in such a way that they may accomplish more than they do now with the same expenditure of time. This is a work that no other society can do so well, and it need not interfere with the regular work of the Society.

The writer would respectfully urge that a committee be appointed at this meeting in such way as the Society may see fit, and with such powers as may seem best to the members present.

DISCUSSION.

PROFESSOR G. D. SHEPARDSON desired to call attention to one way in which work of this kind is done to a small extent. He referred to the very commendable feature of the catalogues of some colleges, which print each year a list of the graduating theses of the students. Some catalogues contain complete lists of the theses subjects in preceding years. By watching these it is possible to obtain a fair idea of the sort of work which is being done in various colleges. That feature of the catalogues at a very few of the colleges might be well adopted by others. At the University of

Minnesota the topics of the theses have been published to some extent in the *Quarterly Bulletin* and *Students' Year-book*, but they have not been published in the catalogue.

PROFESSOR G. W. BISSELL called attention to the fact that there are two institutions in the country that go a little further than this. Cornell University, through its engineering magazine, the *Sibley Journal of Engineering*, publishes the theses of the graduating classes, the most notable ones in full, and the major part of them in abstract; and the University of Wisconsin issues, he understood, a quarterly magazine devoted largely to the presentation of the results of investigation conducted by faculty and students alike. It seems that these are two worthy examples along the lines suggested by Professor Benjamin.

PROFESSOR STORM BULL desired to make a slight correction of Professor Bissell's remarks. The students have just started an engineering quarterly journal at the University of Wisconsin in which some of the theses will find a place; but the Bulletin of the University of Wisconsin, in which are published results of investigations in various lines, in history, in political economy, in engineering, is the one he really refers to. This Bulletin is published as often as need be. That is, if it is found that something has been done which is worthy of publication it is published; otherwise not; and so at intervals, a Bulletin of the University of Wisconsin is issued.

**ON THE DESIRABILITY OF INSTRUCTION OF
UNDERGRADUATES IN THE ETHICS OF
THE ENGINEERING PROFESSION.**

BY CHARLES CARROLL BROWN,

Bloomington, Ill.

The subjects of ethics, compensation and qualifications are too intimately connected to be entirely separated, and the two latter must be considered more or less in discussing the former. The profession of engineering is too young, in this country at least, to have its status fully defined, and proper recognition of its high position in the world's work has been retarded by ignorance of its value and noble character. The writer is not one who considers engineering simply as a trade or handicraft, though most laymen and too many persons calling themselves engineers take that low view of its position, but he emphatically demands its recognition as one of the learned professions, quite as dignified as any of them and more valuable to the community at large. The low estimation in which engineering in general is held, is due largely to public ignorance and to the incapacity of the many self-styled engineers with which the country has been flooded. The large amount of engineering work to be done in comparison with the number of skilled engineers, and the public ignorance of the necessary qualifications to secure good work, have been the opportunity for the many surveyors and surveyors' helpers to develop rapidly into full fledged engineers in name, but seldom in capacity and knowledge. After many expensive lessons the public will begin to learn that one

must be even more careful in choosing his engineer than in choosing his attorney. The eastern edge of this country has begun to learn this, but as one proceeds west he finds a less and less favorable view taken of the standing of the engineer. The influx of the large number of young men with technical education is improving the personnel of the profession materially, and this will finally have its effect, but there are some retarding factors whose removal would permit more rapid improvement. The ambitious young engineering graduate shortly discovers the unsatisfactory condition of the profession and the difficulty, sometimes the impossibility even, of securing adequate financial return for his labors, and in most cases either withdraws from the practice of his profession to enter some of the side lines in which his technical training is of value, or drops into some salaried position where much of his independence is lost, but a fair living is made secure. This is considered necessary because in the legitimate practice of his profession he must contend with the lack of understanding of ethical principles among his brother engineers, and especially among the incompetent self-styled engineers; with the low prices for work set by these incompetents and adopted by too many others whose work is really of value; and with the ignorance of the public which gives the opportunity for much of this. A proper understanding of the relations of engineers to each other and to the public, and a legitimate combination to secure full credit for ability and education where it is due, and corresponding exposure of pretensions without foundation, will do more

to advance the status of the engineering profession than years of the desultory discussion that has heretofore occurred. There is a serious lack of knowledge of the principles of ethics and the value of the profession technically and financially among young engineers, which can best be removed by some instruction in these principles during the college course. A few lectures upon the relative standing of the profession, the duties of engineers to themselves, their brother engineers, their clients and the public, the history of the profession in this and other countries, will take little time and will be of vast benefit to the future of the profession and to the practical success of individual engineers. Codes of ethics have been proposed at various times, but without causing more than a ripple of interest in the subject, and usually calling to the front one or more of the men who consider their profession as a handicraft, without sufficient dignity to warrant the adoption of a code. These objectors usually belong to the class described, of young men ignorant of, because uninstructed in, the principles of ethics and the value of the profession, who take their low ideas from their personal experiences and an extremely one-sided view of the case, and the consequent despair of anything better. The instruction to undergraduates, proposed, will greatly help to keep individuals out of this slough of despond by giving them a wider outlook and a more comprehensive view of the field and its possibilities. No time need be taken from the regular work, and two or three lectures from competent practical men will cover the ground. The writer's experience indicates that, with a few exceptions

among men who have been in practice to some extent, the college professor is not usually well enough informed on the subject to be fully capable of giving the desired instruction, as a certain amount of experience and contact with all classes of clients is necessary to acquire full knowledge of the difficulties that will beset the young engineer. The question of a formulated code of ethics will largely settle itself in the future if the matter of education of young engineers in the principles of the subject is taken care of. The members of the profession should have sufficient *esprit de corps* to make a written code unnecessary, but it may well be considered necessary to take some measures to protect the profession against the inroads of incompetent aspirants for professional employment while the public and the profession at large are in process of education to the high standard set by our best engineers.

DISCUSSION.

PROFESSOR M. E. WADSWORTH desired to ask for information, what is done in the different institutions in that direction? At the institution with which he is connected the subject of engineering contracts and the question of ethics and principles of engineering is taken up in connection with mining engineering and with mine management and mine accounts. Is not some provision of that kind made in almost all of the colleges?

PROFESSOR L. S. RANDOLPH said that this was a subject in which he had been very much interested for some time. There was a very interesting discussion before the Engineers' Association of Virginia some few

months ago, on the subject of engineering ethics. The subject is one to which the speaker had given some attention, had suffered from to some extent and about which he had heard a great many complaints. The author states that there is serious lack of knowledge among the young men. The speaker's experience has been that the lack of knowledge exists also among the older men of the profession, and the subject is one which it is very important that we should advance. There is still hope of having a code of ethics adopted by the older men. The only practical thing to do is to see to it that the younger men have proper ideas when they graduate. As to the best method of handling this subject the speaker's practice has been to introduce it here and there through the course as opportunity offers. It is not always possible to arrange, in the case of engineering ethics, a distinct course in the school, but a great deal can be accomplished at times by an anecdote, perhaps on a hot day, when the class will not listen well to a serious subject, but can be roused with an anecdote. A good deal can be taught in that way, if the subject of engineering ethics is brought up incidentally in a way to excite the student's interest and either amuse him or make him angry at some species of injustice. The subject ought to receive attention; the speaker's experience has shown that. Within the last two weeks a man who signs himself as a civil engineer came to the speaker to ask him how to calculate the head necessary for a given flow through a pipe; he had a problem of that kind; he wanted to lay out a ditch for carrying the water some distance, and then take it the rest of the

way through the pipe; he came to ask how to calculate the head. If he had squarely asked for information the speaker would have told him what little he knew on the subject. That man was evidently feeling around in an underhand fashion, trying to find out in some way how to do it. He was utterly incapable in all probability, and yet a great deal of bad work had been done by him and is doing injury to the profession of civil engineering.

PROFESSOR E. A. FUERTES thought the subject to be a very important one, for it is convertible into that of social position and comfort in life through suitable fees. A man who feels that his economic value in society is great is not going to work for a dollar and a half per day. The speaker believed with Bolivar—the South American Washington—that “no one ever gets anything better than he deserves.” The reason why our profession suffers in the way of which we complain, is because it is not like the French body of engineers, which is composed of men who are, *ipso facto*, cultured gentlemen of great social power. The reason why we have not yet such power is because we do not deserve it; there cannot be any other reason; it is the only reason that could exist. If our young men were better educated, not alone in the “bread and butter subjects,” which seem to be the main object of many of our engineering courses, they could be so rounded and empowered that they would become great social forces to influence other men in the way that men can only be influenced. This must be by personal force, and that personal force cannot be recruited excepting by that kind of education which

enables a man to have a thousand phases like a diamond and enables him to reach and control many varieties of interests and sympathies. Then again, in this country, the freedom that permits any man to do anything he pleases unless somebody else is injured by it and takes the trouble to go to law, enables John Doe or Richard Roe to put a shingle on his door calling himself a "Civil Engineer," and no one says anything against it. No policeman goes to him and has him put in jail, as he ought to be, for trying to live under false pretenses. That leads the speaker to think that possibly the influence of the Society, with more argument and endeavor, might perhaps cause the Legislatures of the various States to pass laws forbidding people from practicing the profession unless they have been educated as engineers or else have been in some way licensed by a body that offers suitable guarantees. As it is now, the lawyer who collects his bills, whether he wins or fails, cannot practice without a license. The same obtains with the physician, with the advantage that the physician enjoys the privilege of burying his mistakes, whilst the engineer is generally buried by them. If it were possible to pass such a bill, a law should be enacted that would prevent incompetent men from taking into their hands the lives of hundreds of thousands of people who entrust themselves to the engineer daily on engineering works, railroads, public buildings, bridges and vessels on the high seas. There is now as much danger to society at large by the lack of education on the part of engineers as there is from the lack of education on the part of physicians or lawyers.

PROFESSOR C. F. ALLEN spoke of a case which came under his immediate notice, of one engineer who had the right idea of such matters. As Locating Engineer of a railroad this man received \$250 a month. As the work progressed he was informed that the company would be very glad to retain him as Chief Engineer at the same salary. The road was an important one and he told them what the speaker believed was right, that the salary was insufficient for the position ; and this engineer refused point blank to accept the situation at that salary. The question was asked if he would remain for a time as Locating Engineer at the same salary and this he said he would do; the salary was, for this position, sufficient. In other words, the man fully appreciated the dignity of the position. He was in every way a splendid fellow. Earlier in his career, while waiting for certain important work to develop in Colorado, he was willing to take his shovel and work upon a toll-road that was under construction, although he was able to loan to the contractor money to continue his work. This man was not above working with a shovel and yet was unwilling to lower the dignity of the profession in accepting at an improperly low salary, a position which was offered him in the light of a promotion. The speaker's classes have generally, in fact every year, been informed of that case.

THE STUDY OF MODERN LANGUAGES IN ENGINEERING COURSES.

BY THOMAS M. DROWN,

President of the Lehigh University, South Bethlehem, Pa.

Modern languages are a part of the professional equipment of the engineer. He must read German and French with ease or he will not be able to keep abreast of the progress of his profession. It is, therefore, a question of the first importance how, in the crowded curriculum of an engineering school, these languages should be taught so as to secure the greatest practical result in the time assigned to them.

To this question it may, perhaps, be answered that the engineering school is no place for the study of languages, that the students should be prepared with a good reading knowledge of German and French when they enter. This disposes of the subject in a summary and highly desirable way, but in the present condition of preparatory schools and college entrance requirements we have to deal with students who, though they may have an elementary knowledge of these languages, are unable to read technical literature with fluency.

It is true that one at least of the prominent technical schools of the country requires German and French for entrance and does not include them in its courses of instruction. But I think it will be generally admitted that the instruction in the preparatory schools in these languages must be supplemented by instruction or practice in the engineering school if the student is to feel himself at home with foreign engineering periodicals.

The study of modern languages in engineering schools has two objects, first, the one we are now considering, namely, the acquisition of a reading knowledge of the languages which will enable the engineer to get quickly, and at first hand, information from foreign sources, and second, the acquisition of a general knowledge of these languages and their literature.

I do not propose in this paper to enter into the discussion of how much or how little of general culture studies should have a place in the engineering curriculum. I have in another place* expressed my conviction that English, history and political and economic science, as well as the modern languages, should have their permanent places in the courses of instruction in engineering schools, for the reason that young men enter these schools, not as graduate students, but at the same age at which they enter college and with the same preparation. If the engineering schools provide for them merely the branches essential for the engineer, architect or chemist, the young man is graduated with a one-sided training in which the humanities are absent. Until the engineering schools can draw their supply from college graduates, or at least from students who have spent two years in academic studies, I hold that it is the duty of educators in technical schools to see to it that the young men under their charge get something more out of their course than mathematics, mechanics, physics or chemistry.

But the question now before us is whether there is any way by which the student can quickly learn

* "The Educational Value of Engineering Studies," an address delivered on Founders' Day at Lehigh University, October 10, 1895.

to read foreign books and journals on technical subjects with ease and accuracy. My experience has shown me that this can be done if the student appreciates thoroughly that a knowledge of modern languages is a necessary part of his equipment as an engineer or chemist. One of the difficulties that a teacher in a technical school has to contend with is the obstinate resistance the student opposes to the introduction of anything into his course of instruction for which he does not see immediate use in his profession.

In order that the culture studies above mentioned may be successfully taught in technical schools it is necessary to have teachers of these branches who shall possess both the inspiration and the tact to interest students. But in the case of the modern languages it is only necessary to introduce the student to the wealth of professional knowledge locked up in foreign periodicals in order to stimulate him to earnest effort to possess himself of the key.

My practice at the Massachusetts Institute of Technology, where I was for many years connected with the chemical department, was to take as a reading book for the class in chemistry in the Junior year a well-known German periodical of analytical chemistry after the class had had one year of preparation in German grammar and in simple reading exercises. The students were generally appalled at the idea that they were expected to read a work of this character after (as they thought) so slight a preparation, and they were astonished to find in the course of a few weeks that the exercise had lost all terror for them. After a few hours in the class room,

in which I found out how much they knew about the construction of German sentences, I began to discuss with them the subject-matter of the articles we were reading. By selecting subjects with which they were more or less familiar, and operations which some of the members of the class were, perhaps, working on in the laboratory, the exercise became a chemical conference on recent German literature. By holding to this idea throughout the remainder of the year the students lost sight of the language in the matter, and during the Senior year there were very few students of chemistry who did not consult German books in the library with ease and confidence.

Another suggestion may be offered in this connection which I have found very helpful and which I owe to Dr. Wolcott Gibbs, who made it to me in my student days. It is that the student should read by himself a brief, illustrated, elementary text-book on chemistry or engineering, as the case may be. The similarity of many technical words in French and German with the English, the reference in the text to illustrations and diagrams, the usual simplicity of the construction of the sentences, combined with the reader's general knowledge of the subject treated, will enable him to read the book with comparatively little reference to the dictionary.

In a word, I would recommend that the modern languages should be taught to students who have had one year's preparation in the grammar, by the instructors in the department in which they are studying. To have this professional reading under the charge of the language department will not answer

the same purpose. It is necessary that engineering German should be taught by one who has at the same time a knowledge of both German and engineering.

The use of "scientific readers" in French or German—a collection of scientific and technical articles by well-known authors—is an attempt to do this work within the department of modern languages. But in reading these the student does not ordinarily lose the idea of drudgery in getting out his lesson and he does not feel that he is making any progress in his professional work. These books seem to me to have no advantage for the technical student over general classical literature, and the latter is usually more interesting and profitable reading from the standpoint of general culture.

Again, let me say that, in advocating this method of teaching German and French in technical schools, I am merely aiming to accomplish an important practical end in the shortest possible time. The instruction in modern languages and literature, with the object of interesting students in the humanities and broadening their views of life and its activities, is an entirely different matter. This instruction should, of course, remain with the department of languages, and the more time that can be devoted to it the better it will be for the student of engineering.

DISCUSSION.

PROFESSOR DEVOLSON WOOD wrote that our courses of instruction are becoming so crowded that we should adopt the best text-book upon any subject and not use an inferior grade for the sake of foreign technics.

Many years ago he used a French work on hydraulics partly to get the results of the latest experiments and partly for the technics. It worked well, but he had seen no necessity since for so doing. The Professor of Modern Languages at the Stevens Institute of Technology uses in the class room technical works in French and German.

PROFESSOR STORM BULL said that he was very much interested in the paper. What specially pleased him was that the author emphasized the fact that the German and French which should be learned by engineering students is not the classical German, not the grammar part especially, but the useful language. The way in which these languages have ordinarily been taught in most engineering schools has been the way in which they have been taught to the general student; they have been taught as if the students were to become linguists. That is, they have been drowned, you might say, in a sea of grammar and they have been disgusted long before the first year is over. If it is possible, as was stated in the paper, to make students read scientific German after one year's work, it is very good. The speaker had his doubts about it. But if it is possible to succeed with it in the manner described in the paper he would be very glad to have it carried out. Then, again, the suggestion that this scientific and technical German should be taught by the men who are interested in engineering, or by engineers themselves, is a very good one. At the University of Wisconsin the use of German engineering text-books has been tried. The students are supposed to have a two years' preparation; they are supposed to have had this in

the high school; yet when they come to the University they are hardly prepared to read these German engineering text-books, because of incompetent instruction, and as a result, even after one year's work at the University they do not read engineering text-books fluently.

PROFESSOR E. A. FUERTES remarked that in arranging the curriculum the subject of languages for an engineer was one to which he had given a great deal of thought. Cornell University formerly required its students to take languages within the University, believing that in this way they could be taught better. But the growing necessities of the case made it desirable at first by degrees, and finally suddenly, to crowd out the languages and require that the students should enter from the schools with linguistic training, because there seemed to be absolutely no difference in their lack of readiness to translate French or German, especially German, whether the men were taught at Cornell University, whether they came from Harvard, Yale or Columbia, or from the public schools. The speaker had become convinced that the trouble and inefficiency in this direction lies in the methods pursued by language teachers. The men are not taught languages for the purpose of reading technical works, the purely literary tendency being the aim of this kind of teaching. The teachers in the public schools, where the work of preparation is mainly done, are monuments of patience and faithfulness and deserve an immense amount of recognition from everybody. But in the public schools they are overworked and underpaid and have a great many disadvantages

to contend with. They have not been educated for the purpose of teaching languages so that it may be of use to the engineer. Usually all these teachers are graduates of classical colleges ; they are steeped in the theories and especially the prejudices of the classical graduate ; he desired to speak of this very respectfully.

The speaker had tried all manner of ways to obtain, to foster better teaching for his purposes, even having a subsidiary course within the college of engineering, and requiring students to have three exercises a week, during one term, in what was called, in the curriculum, "technical reading in foreign languages." This language teaching within the college gave so much trouble, required such an amount of labor and yielded so little in results that it had died of neglect and had been absolutely abandoned. There is much uncertainty, under existing conditions, as to how this evil may be remedied. The speaker is conscious of the necessity the engineer has of knowing more than one or two languages; and there is much of value, daily written in other languages, that becomes old when it reaches a translation, so that it is quite desirable that the young engineer should be familiar with more than one language in order to keep in quick touch with professional progress. It is suggested that the teaching of languages should be put in the hands of the engineer; but though there are a great many engineers who have had a classical education, and even are natural linguists, the speaker knows of but few of them who would undertake such a task or be good language teachers. It is not only the utilitarian side of this question that commends it as a part of

the engineer's education. The study of the languages improves character, personal sympathies, and sympathies in many directions, and fits men for better, more just and higher conceptions and appreciation of life. But there is, as yet, so little sympathy between the mediæval scholasticism of our universities and the naked utilitarianism of our professional colleges, and such disorganized relations between the lower schools and colleges and universities, that one despairs of reaching, very soon, the ideal neutralization of this unfortunate antagonism. This, however, if true, should not deter this Society from aiming at the most perfect type of Engineering Education and from working hard for its accomplishment in the direction of humanizing the engineer; he needs it more among us than among other peoples, the English alone excepted.

PROFESSOR H. W. TYLER stated, with reference to a remark of Professor Bull, that it might possibly be of some interest for the speaker to say that he was one of the students who took a course such as was outlined in Professor Drown's paper, although it was not taken with Professor Drown. But the conditions in the East are probably different from what they are in the West. Western students are likely to have had a year in German at the time of entering the second year and would not be sufficiently mature to undertake technical reading in foreign language at that time. The students referred to in this paper have had only a year in German at the conclusion of their second year in the Massachusetts Institute of Technology, and by that time have had elementary technical training to such an extent that they can reasonably begin the technical works in French and German in their third year.

PROFESSOR C. C. MESS thought undue emphasis was laid on the fact of the insufficiency of the preparation in German or languages with which students come to the technical colleges. By way of illustration, and he wished to emphasize it, a gentleman not very many miles away from this spot at this moment—and, he will not be offended if it be stated—knew very little of either German or French, but did know a good deal about a subject upon which he was called to accumulate authorities, with the result that in two or three weeks, by virtue of his knowledge of the subject, he was able to read the language with ease. This means that in the higher classes, in the junior or senior classes of the technical institutions, it will not be at all difficult to make very rapid progress in the reading of technical literature, because the student knows what he is trying to get at—something about the subject he is going to read. In the case of a French book in mechanics, for instance, without knowing a word of French, if one understands equations pretty well, it may be possible to read the whole book. Whether the book be written in French or German, it is possible to read the book if one understands the mathematics, without understanding French; but if one understands French without understanding mathematics it will be impossible to do so. Some injustice may be done if we try to inoculate the technical study of language too early. Good results could not be reached in making children read technical literature when they have not the least idea of the subject they are trying to read. A man who may be a good reader and perhaps familiar with Shakespeare, as well as fully informed on the topics of the day, if given a book on

applied mechanics, will have a hard time understanding it.

PROFESSOR STORM BULL thought that there is quite a little difference between French and German in this respect. Professor Mess has reference more particularly to French and, according to the speaker's experience in Wisconsin, students who have studied French one year, could get along very fairly. But, on the other hand, his experience was that two years of German at the University did not bring a student farther than one year in French. Besides, there are scientific German books which it takes an expert to decipher.

PROFESSOR M. E. WADSWORTH desired to ask a question : Could not the difficulty that Professor Fuentes has spoken of, be done away with by taking the stand that is taken in other professions, *i. e.*, that the so-called general training studies should be left out of the engineering curriculum? Is it not possible to occupy a high plane and say that the engineer is just as advanced professionally as anyone else? Can he not start his professional training where the other professions do? Instead of asking the incorporation in the engineering college course of English Literature and numerous other subjects that belong to general culture and education, should they not be put into the preparatory school where they properly belong? The engineering profession is belittled by starting its education so low. Is it not possible to start it on the same plane that other professions select? In this way it would seem that the colleges could have genuine engineering courses and not be obliged to sacrifice their engineering studies to the continual demand for the interpolation in the course of literary subjects.

THE METHOD OF TEACHING PERSPECTIVE TO ENGINEERING STUDENTS.

BY HENRY S. JACOBY,

Associate Professor of Bridge Engineering, Cornell University, Ithaca, N. Y.

If a transparent plane, called the picture plane, is placed between any given object and the eye of an observer, called the station point, there may be conceived to lie in the plane, a picture of the object, every point or line of which covers the corresponding point or line of the object. A drawing in plane perspective is one which is constructed, by some method, on a plane surface so as to be exactly equal to the one supposed to lie in the transparent plane. Several methods of making this construction are in use.

The first method is that of direct projection, in which any point of the picture is located by drawing the line of sight from the station point to the corresponding point of the object, and finding where it pierces the plane of the picture. It is seen, therefore, to be pure conical projection. This method requires both the horizontal and vertical orthographic projections of the lines of sight to be drawn, and hence needs a complete plan and elevation of the object, the picture plane, and the station point, in their true relative positions. If the object is set obliquely to the picture plane, more than one elevation is necessary. If the plan and elevation of the object are furnished to the draftsman this method requires only a very elementary knowledge of orthographic projection on his part. Its

disadvantage lies in the fact that a larger number of auxiliary construction lines must be drawn than by any other system, and these tend to cause confusion and to obscure the required lines. It is also very difficult to remember which are the corresponding points during some parts of the operation.

The second or mixed method is that in which the abscissa of any point of the picture is located by direct projection, and the ordinate by the use of vertical measuring lines and auxiliary intersecting lines vanishing on the horizon. This method has been properly characterized by Professor Ware as deficient in scientific unity. The objections to the first method also apply to this one. However, it is probably in more general use than any other.

In the third method, or that of co-ordinates, every point is located by its three co-ordinates, parallel and perpendicular to the picture. The x and z co-ordinates are laid off directly in the picture plane, while the y co-ordinate is determined in direction by means of its vanishing point, and measured by means of an intersecting diagonal in perspective. If the leading lines of the object are perpendicular and parallel to the picture plane, only perpendiculars and diagonals need to be used. If the object is placed with its leading faces at an angle to the picture plane, measurements are required to be laid off which are not obtained directly by measuring any line of the object itself, two such measurements being required for every point. While this method involves an excessive amount of labor when employed exclusively on any drawing, it is of great value in connection with other methods, in

locating some important primary points at which principal lines intersect. In special cases, however, an object may be so irregular in form that most of its points may be conveniently located in this manner.

The fourth, or the method of squares, is a modification of the preceding method in which the plan is covered with a network of squares whose sides are parallel and perpendicular to the picture plane. These squares are reproduced in the perspective of some horizontal plane which may either coincide with the horizontal co-ordinate plane, or lie above or below it. The heights are obtained by drawing in perspective a series of equidistant horizontal lines lying in a profile plane at the side, the lines being at a convenient distance apart and referred to the datum of elevations. This method would be especially useful in constructing the perspective of those features of an object which may be given by means of contour lines.

The fifth method is that in which the perspective of the edges or other lines of the object itself are determined in direction by vanishing points, and in length by points of distance and lines of measure. The position of the starting point is usually found from its three co-ordinates, and from this point the lines follow each other in succession as they are connected on the object.

The highest development of this last method, so far as it appears at present in any published form, is not restricted to lines and points, but extends to planes and thereby simplifies the construction by the application of a number of familiar principles in orthographic projection. Before giving some illustrations

of this fact a few other terms should be defined. An initial point of a line is where it pierces the picture plane. As a line has a vanishing point and an initial point, so a plane has a vanishing trace and an initial trace. In orthographic projection, if a plane passes through a line its traces will pass through the corresponding traces of the line. The application of this principle to perspective is that if a plane passes through a line, its vanishing trace must pass through the vanishing point of the line, and its initial trace must pass through the initial point of the line. In a similar manner all the relations of points, lines and planes which are employed in orthographic projection may be advantageously applied in perspective. This materially reduces and simplifies the construction which by other methods would be wearisome and complicated, and further, it is possible to so arrange the work that the least number of auxiliary lines shall cross the part of the sheet covered by the finished perspective drawing.

The greatest advantage of the method, however, is that it enables the draftsman to dispense with the use of the orthographic projections of the object, to make the construction in perspective directly from measurements of the objects and to check the work by suitable tests similar to that of closing the plat of a survey.

The principles and practice of orthographic projection are included in the curriculum of every engineering college in the country, and if not indicated in the register under the title of descriptive geometry, its elements are included in some other course in drawing.

That method of teaching perspective to engineering students should, therefore, be employed, which furnishes the best application of the preceding portion of the course in descriptive geometry, especially if it has the advantages named above. Since descriptive geometry appeals more strongly to the imagination of the engineering student than any other subject in his course of study and is of the highest value because of its intimate relation to designing, it is a decided advantage that the work in perspective should be so arranged as to constitute additional practice in the application of its general principles. Not only will the entire course have greater scientific unity, but the maximum of thoroughness for the limited time usually allotted to the subject will be secured.

As perspective is usually treated in the text-books, the definitions and notation covering nearly the entire subject are massed at the beginning, and then the construction, so far as it relates to rectilinear objects, is developed under the three divisions of parallel, angular and oblique perspective. The massing of definitions requires an unnecessary tax on the memory, while the subdivision referred to is not as logical as it should be, because the principles involved are not essentially different in the three classes, being based on the position of the object with reference to the picture plane. So many new ideas are introduced in parallel perspective that the student has not time to fix them properly in mind in the solution of problems. Again, by beginning with the special cases and proceeding to the more general, the impression is somehow received by the student that the same principles do not equally apply

to all positions of the object. For instance, there is a decided tendency to consider that points of distance are only 45° points, as they happen to be for lines normal to the picture plane, or that they must always lie on the principal horizon.

A thorough re-examination of the whole subject during the past year together with tests in the class room confirm the conclusion that the more logical arrangement is to begin with initial and vanishing points, and thoroughly fix these in mind by finding them for lines which are oblique as well as horizontal, the lines being given by means of their projections, so that no perspective measurement is required. The next step is to find the initial and vanishing traces of planes in the same way, the planes being oblique, horizontal, vertical or parallel to the ground line, and given either by their orthographic traces or by the projections of horizontals and lines of greatest declivity.

These exercises should be followed by a series of carefully graded problems which involve as many as possible of the relations of points, lines and planes, without introducing the idea of the measurement of length, as follows: Intersecting lines, a plane passing through two lines, a plane through one line and parallel to another line, the horizontal projection of lines, the intersection of two planes, a line piercing a plane, a line lying in a plane, a line lying in one plane and parallel to another plane, a point in a plane, a line perpendicular to a plane, a plane perpendicular to a line, a plane perpendicular to a plane, the angle between two lines, the angle between a line and a plane, and the angle between two planes.

This part of the course recommended is a considerable expansion over that indicated in any treatise so far as known to the author of this paper, and merits the most careful consideration. In the solution of these problems, as for instance in finding where a line pierces a plane, the same procedure should be followed in perspective as in orthographic projection. Special attention is called to the importance of the perspective of the horizontal projection of a line and its relation to that of the line itself. After the student has handled these problems he should be able to find initial and vanishing points and traces so readily that the time and thought required afterward for these elements will be exceedingly small, but may be concentrated chiefly on the new features.

At this point the method of measuring a line in perspective may be introduced. It involves the use of the isosceles triangle as employed by the surveyor in obtaining the length of a line crossing a pond, where a line is measured on the shore, forming with the given line either a complete isosceles triangle, or with the corresponding portions of its sides intercepted between the base and a line parallel to it. Only lines which lie in the picture plane may be measured directly by the scale, while any other line is considered as one side of an isosceles triangle of which the other side is in the picture plane and called a line of measure. The vanishing point of the base of the triangle is the point of distance, and with its aid the base and a parallel to it can be drawn in perspective so as to cut off any given distance on the given line. After some points of distance and lines of measure are found

by the student for lines of various directions and positions, points may be located by their three co-ordinates, also lines which are given in several ways, either by points or angles, followed by the construction of plane figures like triangles, squares, hexagons, etc., having various positions and inclinations. Solid figures like cubes, prisms, pyramids, and other simple forms may next be constructed in any desired relation to the picture plane or to the given planes supporting them.

Such an order of procedure should be adopted as will make the necessary dimensions the easiest to take from the object, and those which would naturally be used in its own construction, including lengths, plane and dihedral angles. By the solution of a larger number of simple problems in each of which a few principles are applied, while the series is a progressive one and covers all the principles required in any case, the student makes better progress as a rule than if he attempts to work out a few of a more elaborate nature in which usually there is a great deal of repetition of the more elementary processes requiring much time on account of the multiplicity of details. Moreover, problems containing fewer lines are adapted to solution on the blackboard during the limited period of the recitation hour, and the instructor is able to more readily detect errors of construction in drawing exercises and to guard the student against their repetition. The student's time should not be used in undue measure, in testing his ability to read the orthographic projections of unfamiliar objects.

It may be desirable to add that probably the most convenient form in which to give the problems to the

student for blackboard work, consists of cards containing sketches of the orthographic projection with all the necessary dimensions marked on them, and showing the relations of the object to the picture plane and station point. An extra ground line will usually be needed, as the object is behind the vertical or picture plane. The solution of suitable problems, and many of them, is regarded as an essential element in the study of all other branches of mathematics, and the text-books furnish them. It therefore seems strange that in descriptive geometry, which is graphical mathematics, the same need fails to be recognized.

By following the order of the presentation here recommended and the corresponding arrangement of suitable problems, this subject, which is so often regarded by students as a difficult one, may be made attractive, while at the same time a larger amount of good work may be done than is ordinarily covered in a manner anything but satisfactory.

Nothing more need be added regarding the balance of the course except to indicate the need of some useful practical hints in regard to the limitations of plane perspective, on how to select the proper value for the distance of the station point from the picture plane, and on the use of the perspective plan and some labor saving expedients to be used in actual practice.

DISCUSSION.

PROFESSOR ALBERT KINGSBURY said he was unable to follow that part of the paper which possesses the greatest interest to him without the aid of diagrams, and he looked forward with anticipations of pleasure

to reading the paper in its published form, with the hope of obtaining some light for use in his own teaching upon the subject. Certainly if Professor Jacoby has devised a method of constructing perspective drawings which does away with the construction of the orthographic projections of the objects represented, he is to receive the thanks of all concerned. In the first part of the paper there was a statement to which it seemed that partial exception could be taken, to the effect that if the object—for instance, a rectangular solid—is placed in a position oblique to the picture plane, more than one elevation is required. That seems not to be true except for such objects as require the construction of more than one elevation in order to get the elevation and the plans which are actually used in constructing the perspective. In this direct method the construction of a perspective drawing is a problem in orthographic projection and it is to be considered as such throughout. Every point on the object, if given by its two projections, is definitely located and two projections only are necessary to determine its perspective.

PROFESSOR W. K. HATT said that Professor Jacoby must be congratulated on the skill with which he has made interesting and clear a subject difficult to treat without the aid of a blackboard. The method of making perspective drawings direct from a measured object, or from the object as pictured in the imagination of the draughtsman, without the aid of plan and elevation, will commend itself to every one as a simple and time-saving device. The method described by Professor Jacoby would be found in a book on "Shades,

Shadows and Perspective," by Professor John E. Hill, now of Brown University, formerly of Cornell University. It seemed to the speaker strange, however, that it appears so difficult for the student fairly well trained in descriptive geometry to understand and apply this method. The operations are simple enough. Apparently the drawing of an object in perspective consists in performing repeatedly two very simple things: finding the vanishing point of a line and measuring off a desired distance on its perspective. Certainly it would be possible to teach almost any person of average intelligence to do this mechanically in a short time, without his understanding the space relations involved. As a matter of fact, many draftsmen make perspective drawings entirely by rule. He thought the difficulty which most students find is due to their inability to connect the space dimensions with the dimensions measured on the paper. In this subject, as in many others, a good start means an easy goal. Descriptive geometry proves a stumbling block to many students who seemingly have had no great difficulty with any other portion of their mathematical training. It had struck the speaker that there is a lack of classified knowledge on the part of the student to whom every problem appears individual. He should be taught in his early mathematical work and in descriptive geometry, to recognize the class of the problem, and with confidence to apply the proper general method to its solution.

PROFESSOR JACOBY replied to Professor Kingsbury's statement that the idea, in speaking of the necessity for more than one elevation, was not that the plan and

elevation do not fix all the points, but that usually there are a great many details required; in the case of buildings and other structures it is often hardly possible to show all the details by the use of only a single elevation. In ordinary practice, side elevations as well as front elevations are used, sometimes sections also, in order to show certain details; these are used as a matter of convenience, not because of the theoretical impossibility of locating several points by means of the two projections. The method recommended is to follow exactly the same order of construction of the perspective as that followed in the construction of the thing itself; that is, the detail is fixed by measurement from the object to which it is actually attached, and not independently by its relations to the coordinate planes of reference.

MODELING AS AN AID TO INSTRUCTION IN MACHINE DESIGN.

BY GEORGE W. BISSELL,

**Professor of Mechanical Engineering, Iowa Agricultural College, Ames,
Iowa.**

THE use of modeling in the teaching of machine design has been resorted to by the writer as a means of conveying to the student a clearer conception of form. The consideration of the form or shape of machine parts is of great importance in the production of a successful design.

In many, perhaps most, problems which the teacher of machine design presents to his students, the form or contour of each of the several pieces which go to make up the complete machine, can be depicted by a sketch, freehand or mechanical, or shown by photographs, although, of course, the most certain and convincing way of representing said form, even when very simple, is by a model or by an actual construction.

In many cases, however, the part in question may be a casting of such complex form, that the instructor, be he ever so clever, cannot exhibit it with a freehand sketch; and working drawings and models or actual examples are not accessible. For such cases a quickly produced model, however crude, is of great assistance, and an eye and a hand capable of producing it readily and quickly, become valuable adjuncts to the instructor's work. A piece of pattern pine and a jack-knife, or a piece of paper and scissors, can, in the

skilful hands, be the material and tool for exhibiting the desired form. The writer is not possessed of the skill for either of the above, but has had some practice in the handling of the plastic materials used by sculptors in their work, and has turned such practice to advantage.

Modeling clay is very plastic, and, when mixed with oil, is an ever ready material.

The tools for the roughing out of the work and for the finishing touches upon the curved surfaces, are the fingers, together with two or three tools used by sculptors and called "hooks." The latter are easily made by bending lengths of wire into small isosceles triangles, wooden handles being attached at the vertices and the bases being of any desired width. The wide hooks are used for producing flat surfaces, and the narrow ones for digging out recessed portions. Special hooks with the bases curved, can be used for curved surfaces, but the writer finds that to use the finger is quicker than to be select from a multitude of tools. Having the form in mind, a lump of clay is shaped by the hands to a rough semblance of the finished form, perhaps no nearer than that of a rectangular block. Hooks are used to remove excess of material where necessary, and the surfaces are finished with a few strokes of the finger.

On models to a small scale, bosses and other projections are added after the principal outlines have been obtained.

Usually the scale is not important, provided relative proportions are maintained correct.

Where cylindrical portions are a prominent feature,

time may sometimes be saved by building the clay around or attaching it to a piece of wood turned to the right size. Similarly, flat surfaces, such as guides or tension members, can be made of other material than the clay, and incorporated into the model, it being understood that rapidity is important, especially when students are waiting for the result.

Another way in which the clay can be used instructively is in studying the effect of changes in existing constructions. Projections, such as bosses, brackets or fillets, can be rapidly created upon the existing part and the resulting form compared with the original, or with any other form. The writer has had a limited use of this method, and believes that the value to his students of his instruction in machine design is thereby enhanced.

DISCUSSION.

PROFESSOR J. J. FLATHER said that he had been much interested in the paper just read. There were many excellent suggestions in it. He would object to the statement that the scale is not important. He believed that in modeling, one is not entirely certain how a thing is going to look; it is a matter of training the eye and getting something to shape for a part that is wanted. It is a development under the hand of the modeler to suit one's preconceived ideas of shape. If the model is not made to a large scale, the relative proportions will vary considerably from those of the piece in its actual size, and moreover any scale less than full size will develop this feature. This is noticeable in drawings. A drawing of a part is made

to quarter scale or eighth scale, and it gives an entirely different idea so far as proportion is concerned, from the one that is drawn full size. The same thing must hold true to a certain extent in a model made to scale. It does not make any difference what the scale is ; while there may be a resemblance, and while the model may have good clear lines, yet the proportion will be apparently modified, and the smaller the scale the greater will this be shown. In the speaker's own work in teaching design, where there is a part that is very much too large to put on the drawing board full size, as for instance, the frame of a drill press, the student has been encouraged to draw it out full size on the blackboard, so as to get the correct lines, and an entirely different proportion often results when it is thus drawn, from what would be obtained if it were drawn on the drawing board to a scale of say, one-eighth. This refers more particularly to machine forms, where the size of a boss or the curvature of a corner or location of bracket, as well as the general contour itself, will all affect the form of the piece that is to be made. It is found that a student obtains a very much better idea of correct proportions and grace of outline if it is sketched full size than he does if it is a scale drawing. In order to extend this practice, the speaker proposes to have a large slate black-board, say four feet by six, suitably mounted in a swing frame, and divided over its entire surface by fine lines one inch apart. Then after it has been determined what shape and proportions are desired, the design can readily be scaled off and reduced to any convenient size of working drawing. That system is in

use in the shops of Pedrick & Ayer, Philadelphia and possibly in other places.

PROFESSOR W. F. M. Goss did not feel sure that he understood perfectly the purpose of the modeling. Is it that the lines of the machine part may be graceful, and the prominent features of the design well joined?

PROFESSOR BISSELL answered that the object of the model is to clear up hazy impressions in a student's mind as to the shape of a relatively complicated piece.

PROFESSOR Goss suggested that it was then a means of interpreting machine forms.

PROFESSOR BISSELL said that "means of interpreting" expressed the idea very well; it was giving to the student the correct impression of what the form should be to connect certain of the important parts. For instance, in a side crank engine it is desired to connect the shaft and the cylinder and foundation in a certain way, and to provide for the motion of the connecting rods and the reciprocating parts; and it had happened that some students had come to him who had never seen an engine of the Porter type and did not have a very clear conception of what it is; there were no actual models at hand or actual examples, and that was one case in which he applied the method described.

A COURSE IN NAVAL ARCHITECTURE.

BY CECIL H. PEABODY,

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The larger part of the commerce of the world is now carried by iron steamships, and the tendency is more and more toward the use of iron (or steel) for the material for construction, and of steam as the mode of propulsion ; though in some places and for certain purposes, wood is still preferred and sails are still used.

The construction of iron ships and the fitting of their machinery is clearly a branch of construction engineering ; even more so is the management of the yards in which such ships are built.

Following the precedents of the transition period when ships were built by ship carpenters and engined by machinists, there is a tendency to make a sharp division between the building and engining of a ship; one branch is called naval architecture and the other marine engineering. In reality the difference is like that between engine building and boiler making, which are distinct trades, though both engine and boiler are commonly designed by one engineer. Without question, the final responsibility for the ship and her machinery should rest with one man who should be master of both branches of his profession.

This paper will consider that a course in naval architecture should give a sound and well rounded training in engineering as applied to ship building, including both hull and machinery.

The modern tendency toward specialization is found exemplified in the engineering profession, and is reflected by schools of engineering, which offer courses in civil engineering, mining engineering, electrical engineering, etc., and commonly the courses are sub-divided into options. But every competent engineer is first an engineer and afterwards a specialist, and in like manner we find that any course in engineering must first of all give the great body of fundamental principles underlying all engineering work, and then add specialties and options. That which is common to all engineering courses is both larger in amount and more important than that which is different.

All this is so evident as to appear a truism, and yet time and space may be saved by its statement, because there is a general concensus of opinion concerning what forms the main body of instruction in engineering. It is sufficient to name mathematics, chemistry, physics, applied mechanics and strength of materials, and to add modern languages, English literature, history and political economy, to account for the larger part of the time and labor of students in those engineering schools which aim to make men, as well as to train engineers.

Thus we find the major part of our course in naval architecture already laid out for us.

The naval architect has much to do with machinery in all the processes of shaping and working the material into the ship, and must deal with the generation and application of the power which is to drive the ship. To the main body of instruction must be added

mechanism, dynamics of machines, thermodynamics and the theory and practice of steam engineering.

It is not necessary to say at this day that the instruction mentioned should be accompanied by work in laboratories of chemistry, physics, applied mechanics and steam engineering, nor to call attention to the advantage of shopwork in wood and iron.

We may add to the work already laid down the special study of the marine engine and the application of its power to propellor or paddle wheels. Attention should be given to varieties and details and to methods of construction and erection of marine engines. When quick-running engines are used the dynamic action of the moving parts becomes of great importance on account of the stresses and vibrations that are liable to be set up. The principles to be used for an investigation of this action will be taught in the dynamics of machines, but the detailed application to an important engine may well form a part of the special study of marine engines.

The subject of drawing has been left for separate mention in order that it may receive greater emphasis. The ability to represent constructions by drawings and to get from drawings the conception of form and solidity is of prime importance to all engineers; to the naval architect most of all. The importance of descriptive geometry as preliminary training for this purpose can scarcely be overrated, not merely that the propositions and problems are likely to occur in ship and engine drawings, but even more on account of the ability it gives to conceive geometrical and irregular forms, to represent them by their pro-

jections, and to rapidly and correctly read all kinds of mechanical drawings.

A student of naval architecture should make enough machine drawings to become familiar with the methods; his training for facility and finish will be given mainly by the considerable amount of ship drawing that must form part of the course.

The body of facts, experiments and observations, which, with the proper mathematical investigation and reduction, form the theory of naval architecture, is neither very large nor very difficult. All that is accepted as certainly known, whether or not it has or can be used in practice, can be taught in its entirety in a four-years' course of study, together with all the other subjects that have been named as essential for the proper training of a naval architect. It appears to be very desirable that the course in naval architecture should form a regular four-years' course on the same basis as the courses in mechanical and electrical engineering. Of course students who are able and disposed will find it advantageous to take five years and so broaden their training by rounding out their work in mechanical engineering and by taking electricity; but it is true in like manner, that any engineering student will find it advantageous to take two courses if he can.

The special instruction in naval architecture may well begin with a description of the framing, details and method of construction of ships in wood and iron (or steel), which may be given in the second or third year of the course. It might come earlier except that the mathematics required for a proper understanding

of the theory of naval architecture can hardly be attained before the end of the second year, and lack of continuity in the special work of the course is undesirable.

This descriptive work need not be very extensive or minute; it should be enough to enable the student to rightly comprehend other work of the course which presupposes such knowledge, and to recognize work that he may see in process of construction in shipyards. His knowledge of the art of shipbuilding must finally be learned in practice in the shipyard and drawing office. It will be of the greatest advantage to students to get some experience in shipyards or drawing offices in summer vacations, but opportunities for such work will be obtained by a few only.

The theory of the properties of ships may be divided into two parts, statics and dynamics; the first deals with form, displacement, stability and strength; the second with waves, rolling, resistance and propulsion. The first part of statics is mainly geometrical in nature, and can be presented in a certain and definite manner. The second part, various in form and nature, is incomplete in many places and exists largely in the form of the original memoirs. Much of it must be given in its incomplete condition, and this adds to the difficulty of both the student and the instructor.

The determination of the best form for a certain ship has been the result of a slow and laborious evolution, so far as we really know anything about this matter. The only attempt at a theory, that by Scott-Russell, is now discredited. Examples of models and

lines of ships, or still better, opportunities of seeing hulls on the building slip or in dock, can give students some conception of the forms that have found favor, but there is little that can be done in the way of explanation.

Calculation of displacement is soon taught, so far as principles are concerned; the actual work, either numerically, in the form of a displacement sheet or by aid of mechanical integrators, is tedious and laborious. The student should be made to understand all phases of the subject and should get some facility in the application of the methods commonly used; he can become an expert ship computer only by long practice, which cannot be given and does not belong in a course of instruction. The methods which use mechanical integrators are simpler and shorter, and are best adapted for teaching; they should be given first, and then the short arts taken in numerical work will give less difficulty when those methods are explained. This applies with equal force to the teaching of methods of calculating stability. Students should early learn the probable error of mechanical integrators, especially when used for finding moments and moments of inertia, and should understand when the degree of accuracy attainable is, and when it is not, sufficient for the work in hand. Preliminary determination of displacement can be made rapidly and with sufficient accuracy by the aid of the integrators, but most designers will prefer to make the final calculations for the completed design numerically. On the other hand, the probable error of determinations of stability by aid of the integrator is much less than the uncer-

tainty of our estimate of the probable behavior of a vessel at sea from the stability curves for quiet water.

The most complete and elegant presentation of the general discussion of stability is given by French writers, and their method when thoroughly comprehended gives the most complete mastery of the subject and of its applications, especially to such problems as irregular loading, grounding, and opening of compartments to the sea. The criticism of their work is not so much that it is unnecessarily long and abstruse, as that the student finds it difficult to detach and readily account for those problems and methods which are used for the ordinary calculations of the stability of the ship in her normal condition. English writers commonly avoid this difficulty by giving at once the methods used in practice with the necessary demonstrations, and add thereto the problems which deal with additions of weight, changes of trim, etc. Probably a middle course will give the most satisfactory results, presenting first those simple ideas needed to understand the methods of determining stability when the ship is in normal condition and is inclined in a transverse (or longitudinal) direction only. Afterwards there may be presented the general geometrical discussion of the surfaces of buoyancy and of water lines, somewhat more briefly and less abstrusely than is done by French writers. This has the theoretical defect of a double presentation, but it is believed that in the end, time is saved and a better result is attained. The student can easily account for the methods used in the ordinary calculations of stability; he realizes their defects and limitations, and readily grasps the

problems of adding a weight, of shifting or liquid cargoes, of grounding, docking and launching; and he can extend the ordinary methods to practical cases.

The several works and memoirs on stability of ships give a number of methods and a variety of devices for calculating or determining stability. Only two methods appear to require discussion in the class-room; they are the method of cross-curves and Barnes' method. The method by cross-curves not only gives the most complete results, but is the easier to explain, especially by aid of the integrator. Barnes' method may be conveniently given in connection with yacht-work, for which it is well adapted.

The drawing given in connection with work on displacement and stability may begin with drawing the lines of a medium sized steamship, rather full than too fine. The laying down dimensions should be nearly fair, for the student must first learn what fair lines are and how to draw them. Afterwards he may be given the determining elements of a yacht and be required to draw for them a set of fair lines; this has not only the advantage of variety, but will probably enlist the student's enthusiasm. The drawing of yacht lines might almost be considered to form a yacht design, were it not true that the selection of the elements is the real difficulty in such a design.

The lines of the steamship may be used for the determination of stability by the method of cross-curves and the yacht lines may be used for Barnes' method.

The highest quality of work in drawing and calculation should be required of the student from the first, nothing like slovenliness or carelessness should be

tolerated. Rapidity of execution may be demanded later, at the expense of accuracy if that is found necessary.

The formal instruction in the methods of calculating the weight, centre of gravity and strength of the hull, can be made very brief for students who are familiar with applied mechanics and strength of materials. Some existing ship may then be chosen of such construction that the ordinary problems and difficulties met in practice may be illustrated, but at the same time not so large or complicated as to involve too much tedious work. The entire calculation must then be worked out by the instructing force in a satisfactory manner. This calculation is to remain in the hands of the instructor and serve as the standard with which the students' work must agree within an assigned limit of error. Mistakes will be at once known to the instructor, who can, at discretion, warn the student without relieving him from responsibility. The work may commonly be so divided among the students of a class that the entire field may be covered without allowing any one to wait for, or unduly depend on another.

The theory and applications of simple waves in deep water should be taught thoroughly, and the student should learn the effect of superimposing waves, and the effect of shallow or shoaling water on the character of waves. The writer's preference is for a non-mathematical treatment of the more complex parts of this subject.

The rolling of ships in a quiet, unresisting medium may be best approached by first finding the form to

give isochronous rolling, and then to show the effect of other forms on the time of rolling. Rolling of ships in a resisting medium like water, or among waves, cannot now be given in a satisfactory manner, because our knowledge of these subjects is so incomplete; the investigations and discussions are in some cases too involved and obscure to be given profitably before a class. Probably it is best to tell simply and briefly what is and what is not known, and where the literature on the subject can be found, and so rest content till more is known.

After waves and rolling, will come a discussion of apparent weight due to rolling, a description of instruments and methods of measuring rolling, and the effect of apparent weight on such instruments. The method should be given of finding the stresses on the hull when placed in simple waves, including the effect of the instantaneous pressure, or dynamic action. The student should at the same time be made to appreciate that there is no direct way of inferring from such calculations what are the actual stresses that are likely to be experienced by the ship when at sea.

The most difficult and important subject in the present state of naval architecture is the propulsion of ships. Fortunately two recent books by Taylor and Sidney Barnaby have summed up our knowledge on this subject and made it possible to give it in a compact and practicable form, whether or not the methods they propose are entirely satisfactory to others or even to the authors themselves. Students should become familiar with the investigations on which these works are based, either in the original

memoirs or from abstracts, more especially with the work of the Froudes. Some attention should also be given to propulsion by sails.

In connection with the study of propulsion, the students should work out a general problem, determining the size and form of a ship for a specific purpose; for example, to carry a given cargo a certain distance at a given speed. There is a distinct educational value in making a preliminary solution of the problem by a logical method like that proposed by Naval Constructor Woodward, U. S. N. The main dimensions thus obtained are then to be modified by advice of the instructor and will take the place of the data usually assumed by the designer, without such a preliminary solution, as the basis of the design. The student will then both understand and appreciate the tentative methods commonly employed.

Together with the calculation of displacement and resistance, the student should select the scantling for the ship and get the work ready for calculating weight and strength. In some schools of naval architecture the calculations for weight and strength are made in connection with such a problem and the work is considered to form the design of a ship. But a design cannot be intelligently made before the calculations of weight and strength are understood; consequently such an arrangement makes it necessary to give a preliminary problem in that line, thus duplicating work that must always be abridged when given for sake of instruction, and which must in any case appear tedious as compared with other work in the course. The reason for giving a design appears to be largely that

the business of a naval architect is to design ships and that the graduate of a school of naval architecture should show that he is fit for the business of his profession. In other branches of engineering such an idea has fortunately disappeared and we have instead the correct idea, that the graduate of a technical school is a young man who has had certain advantages fitting him to begin and to learn his profession. This is the more important in the case of naval architecture, as the design of a ship is a work requiring the matured skill and experience of one who has mastered his profession and who has at his command a staff of draughtsmen and computers. It is believed that the order recommended will most quickly and efficiently give the training which can and should be given in a school, and that it will give the graduate of the school a more modest and just appreciation of his status, at the time when his profession is all before him.

At some time during the course, probably toward the end, instruction should be given touching drainage and ventilation, and concerning armor and armament. The general principles, so far as they have been developed, should be clearly stated and details should be given to illustrate and enforce them. Adjustments of the compass should be taught, though such matter belongs rather to the navigation than the construction of a ship; but the constructor may greatly aid or hinder the proper placing or adjusting of the compasses, and not infrequently he may be called on to take the entire responsibility, especially in merchant work. In connection with the study of the compass, arrangements may be made to give practice in adjustment

either on board some ship, or more conveniently, on a compass so mounted that it can be influenced by permanent and temporary magnetism, and may be swung to determine and compensate the effect of such magnetism. Other such work, of the nature of laboratory practice, may be devised in connection with some of the subjects taught, and will add to the interest of the instruction; but the students, in common with all students of a technical school, will have a thorough training in laboratory methods, which is the more fortunate as much of the work in naval architecture is not susceptible of treatment in a laboratory. Again, it is more important that students should learn the methods of the laboratory and that they should do something thoroughly, than that they should do some specific thing. As far as possible, however, all laboratory work should be bent to the general trend of the work in a given course, even in a subject like applied mechanics, which is common to all engineering courses. A student of naval architecture will take a more lively interest in experiments on riveting which relate to shipbuilding or boiler-making than in those which relate to bridge work, and yet the latter cannot properly be treated with neglect.

The one prominent application of the laboratory method in naval architecture, is the investigation of resistance by towing a model of a proposed ship in a tank. Such work to be of value must be done in connection with construction of ships, and the ships, when completed, should be given adequate progression speed trials. The tests of the models and the ships form together a work of the greatest importance in the ad-

vance of the theory and art of ship building. Tests on models only are useless or misleading. Consequently it cannot be expected that a tank for towing models can be advantageously maintained as part of a school when instruction is the main object. And yet there is no doubt that students of naval architecture would find much advantage in taking part in the work of such a tank.

If a mould loft is accessible, or if a floor that can be used for such a purpose is at hand, practice can be given in mould loft work, and will be found to be both interesting and instructive to the students. It has been found that students who are familiar at once with descriptive geometry and with ship lines can get a practical mastery of mould loft work in a week or ten days of vacation work.

The naval constructor should know enough of the use of the level and transit, to use them freely in laying out a yard, in making changes in a yard, and in laying out and checking the building of the ship, the launching ways or the hull itself. As an example it has been found in a certain yard, that successful launches can be made under conditions usually considered hazardous, by the simple device of making sure that the launching ways are true and properly supported.

A COURSE IN MUNICIPAL AND SANITARY ENGINEERING.

BY ARTHUR N. TALBOT,

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The growth of population in the cities of the United States in the last twenty years has been very large. The necessity for the construction of municipal public works, especially in the smaller cities, has increased even more rapidly than has the urban population, and the municipalities have not been able to keep up with the demands incident to this growth. Present conditions indicate that the development of cities is to be greater in the future than in the past. Especially in the West is such future development probable, and in this region the present condition of public works is not only behind the material development, but there is a greater necessity for increased and improved construction.

In the same period of time there has been a marked advance in the knowledge of those matters pertaining to the health and comfort of urban communities which are now included in sanitary engineering.

These conditions explain the necessity for a course of study which shall prepare the student for the duties of engineer of public works of cities.

The writer is not an extremist on the question of the specialization of engineering courses. He believes that the primary object of engineering education is the development and discipline of the student along engineering lines, and that professional specialization

must be largely an individual development after graduation, but he is also of the opinion that the best results in engineering education are to be obtained by giving a proper number of special technical or professional courses in undergraduate work which shall direct the attention from generalities to details, illustrate principles already presented, and start the student along the lines of work he intends to take up in future practice. Such a course of study in municipal and sanitary engineering may best be made by modifying the general curriculum in civil engineering and substituting a moderate number of special municipal and sanitary engineering subjects.

It is not necessary to show that the student in municipal and sanitary engineering should have the thorough grounding in mathematics, in theoretical and applied mechanics, including hydraulics, and in general engineering drawing, that is commonly accepted as desirable in engineering courses. The general culture studies should not be omitted. Training should be given in surveying—a course sufficiently general to prepare for street, park and construction work, as well as for land and lot surveying. The elements of bridge and structural work should be taught, and the course in masonry construction is important. The latter should be especially complete in the treatment of cement, concrete, ordinary foundations and substructures.

Of the special subjects, water supply engineering, sewerage, and street and road engineering, are the most important. There has been a great development in each of these subjects recently, and our smaller grow-

ing cities are keen to avail themselves of new methods. In water supply engineering, the improvements in methods of filtration and purification, and the advance of knowledge on standards of purity of potable water and on the relation between the condition of public water supplies and the health of the people, has made this subject of prime importance. Sources and storage of water, the design of distribution systems, reservoirs, tanks and pumping stations, the principles of fire protection, and a discussion of many of the details of construction are essential to a complete course.

The science of sewerage is still in its infancy. Present methods are an advance over those of the past, but it is probable that this branch of engineering is far behind most branches of engineering in its development. This remark applies to the design and construction of the system as well as to the methods of disposal of sewage. The relation of rainfall to storm-water flow, the determination of size and capacity of sewers, the design and methods of construction of sewers and sewer appurtenances, the study of modern methods of sewage purification and disposal, are among the topics to be included. Garbage disposal, street cleaning, general sanitation and sanitary plumbing, are also important parts. For both sewerage and water supply engineering the preliminary training in hydraulics should be thorough.

Street and road engineering, including the improvement and maintenance of city streets, highways, park drives, walks, etc., is a branch requiring special and judicious training. The annual expenditures for these improvements in our cities is so great, and the results

in so many cases so poor, that there is an opportunity for the exercise of the best efforts of the engineer. In such a course there must be considered not only the construction of pavements, but questions of grades, drainage, cross sections, crossings, and methods of maintenance. The testing and inspection of materials and the supervision of construction is important. The improvement of parks and boulevards, so far as engineering features are concerned, and to a limited extent the improvement of the surface of parks and pleasure grounds, are parts of this subject. A minor item which may be mentioned is the fixing of the grade lines of streets so as to add to the beauty of the street, give proper drainage, and yet benefit abutting property.

It is urged that instruction in the foregoing three subjects should cover more than the vague general principles given under the name sanitary engineering in many engineering courses. A proper study of details is as necessary here as in the study of bridge design or of surveying.

Many of the topics involved in water supply and sewerage require previous preparation in chemistry and bacteriology, and the science work should be arranged to include these subjects. The special investigator will require more time on these subjects than the ordinary student will be able to give.

The course in physics should be supplemented with some elementary work in the generation and transmission of electrical energy, and a study of the steam engine and boiler should be given.

But may enough subjects be omitted from the gen-

eral civil engineering course to permit the substitution of the subjects described? In the courses given in many schools it seems to the writer that this arrangement may easily be made. Generally a curtailment of the work in geodesy and astronomy, bridge and structural work, railroad engineering and some subject in science, will permit the arrangement of a course of study which will meet the demands of such work.

Such a course of study will tend to place city engineering work on a higher plane. More intelligent thought will be given to the design and construction of municipal public works. With the growth of our cities must come a more rational system of control of the construction and maintenance of such works, and the municipal engineer not only must aid in placing the department of public works on a different political basis, but must take a high place in promoting the health, comfort and pleasure of the people and in advancing municipal public works to a higher degree of perfection.

DISCUSSION.

THE PRESIDENT remarked that, so far as he was aware, the University of Illinois is the only institution which has a separate, distinct course of study in municipal and sanitary engineering. It is possible, however, that there may be others, and if such is the case, it is desirable to have the facts brought out.

PROFESSOR C. F. ALLEN said that it seemed to him that there is a good field for such a course as is outlined here. The engineering work in smaller cities has not been done as well as it ought to be done.

If men are provided who are well fitted for such work, there would, in his judgment, be a definite demand for them. He believed that the far greater demand for engineers that unquestionably exists at present in the extreme east, is due in large part to the fact that men are provided who can fill places in engineering that could not readily be filled twenty-five years ago.

PROFESSOR W. K. HATT desired to call attention of the society to the fact that in Purdue University there is a professor of sanitary science. The course given includes work in the filtration of water supplies, disposal of sewage and like topics, although it does not include many of those listed in Professor Talbot's paper. In Cornell University, too, there is a graduate course in municipal and sanitary engineering.

PROFESSOR ROBERT FLETCHER said that it seemed to him that the claim of the author that some attention be given those subjects that relate to municipal engineering is a good one. At the same time there is danger here again that there may be an attempt to do some things that the school need not do. As has been said already, the office of the college is to teach those things that the student will not be likely to study when he gets out, subjects that he cannot very well attend to when out of college on account of lack of time, opportunity, or facilities for study and investigation. It seemed to him that this field of municipal engineering is something that each graduate who is called into that line of work must largely develop for himself, according to his environment, and that while some topics which have been mentioned

ought to be treated in the college of engineering, there is a tendency to attempt too much. The graduate practitioner, who is well grounded in the essentials of engineering construction, should be able to lay hold of and apply the needed data and master the special details when the task is before him.

BIOLOGY FOR CIVIL ENGINEERS.

BY GEORGE C. WHIPPLE,

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The civil engineer, in the practice of his profession, makes use chiefly of materials which are lifeless, or, as the chemist would say, inorganic. Iron, stone, sand, brick, cement are inert and almost unchangeable. In dealing with them we may use the rules of mathematics; stresses and strains may be figured and the supporting power of the different materials computed. Mobile substances like water and mercury may likewise be treated from the physical standpoint; their pressure and velocity of flow are ready subjects of calculation. So universal are the applications of physics and mathematics to engineering operations that we are sometimes inclined to forget that the engineer is also concerned with substances which must be treated from a different standpoint.

All engineering work is designed to minister directly or indirectly to the needs of the human being, and therefore, the engineer must be brought more or less into contact with organic matter. This organic living matter is subject to other laws than those of physics; the subtle laws of chemistry and biology play a most important part and must not be overlooked. The object of this paper is to show the practical bearing which the science of biology has upon engineering and to emphasize its importance in the education of engineering students.

The word "biology," used in its broadest signification, means "the science of life," or, better, "the science of matter in the living state." Thus regarded it embraces many subdivisions, as botany, zoölogy, physiology, morphology, etc., which, because they treat of phenomena of life, are called "the biological sciences." The word biology is sometimes used in a more limited sense, as treating of the fundamental principles of life, the nature and properties of protoplasm, and the structure of the cell. This "general biology" is often studied by itself as an introduction to botany, zoölogy and the other biological sciences. Engineers and sanitarians are now using the word biology in a still different sense, applying it to the study of those minute forms of life with which the engineer is concerned and which are more or less closely related to the public health. This division of the subject may be more properly called "sanitary biology" and defined as that branch of biology which treats of the micro-organisms in their relation to the public health. As these micro-organisms include both plants and animals, sanitary biology necessarily encroaches upon the fields of botany and zoölogy.

We may look best at our subject along two lines, according to the subdivision of the micro-organisms proposed by Professor Sedgwick.

<p><i>Micro-Organisms.*</i></p> <p>Organisms, either plants or animals, invisible or barely visible to the naked eye.</p>	<p><i>Bacterial Organisms.</i></p> <p>Requiring special cultures.</p> <p>Difficultly studied with the microscope.</p> <p>Microscopic in size.</p> <p>Plants.</p> <p><i>Microscopical Organisms.</i></p> <p>Not requiring special culture.</p> <p>Easily studied with the microscope.</p> <p>Microscopic in size or slightly larger.</p> <p>Plants or animals.</p>
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The methods used in the study of these two classes of organisms vary greatly. The bacteria, by reason of their small size, cannot be examined directly but must be cultivated in suitable media and studied in mass. It is only by using many different media and determining the character of the growth upon each, that one is able to separate the different species. The microscopical organisms, on the other hand, are much larger; they may be studied easily with microscopes of comparatively low powers.

The history of the study of the micro-organisms is an interesting one. It is closely intertwined with the history of the microscope. Every great improvement in that instrument has been followed by new revelations regarding these lowest forms of life. In 1827 the compound microscope was corrected for chromatic

* Wm. T. Sedgwick. Recent progress in Biological Water Analysis. Journal of the New England Water Works Association, September, 1889.

aberration and otherwise perfected. Its newly discovered optical powers were put to use in connection with the study of the "germ theory." Yeast plants were seen in fermenting solutions and other organisms were observed in various putrefying substances. Little by little it dawned upon the scientific world that the minute organisms, which, at first, were only objects of curiosity, play a most important part in the world's history. Then occurred the hotly contested struggle over the question of "spontaneous generation," which was not settled definitely until Pasteur, in 1855, performed his celebrated series of experiments. The results of that contest have been far reaching, but not the least important have been the new methods brought out for the study of the bacteria. The use of the cotton air filter, the sterilization by heat, and the employment of solid media (Koch's method) for pure cultures, lie at the very foundation of the new science of bacteriology.

Provided with new methods of work and with microscopes of greater perfection, scientists, great and small, began the search for bacteria. Earth, air and water were examined. New forms were found on every hand. The scientific magazines teemed with descriptions of bacillus this and bacillus that. In the midst of many observations which had little value except in stimulating inquiry, there were some discoveries that were epoch-making in their importance. It was proved that certain diseases of man and animals were directly caused by certain specific organisms. Koch discovered the bacillus of tuberculosis in 1882 and that of Asiatic cholera in 1884. In the

latter year Löffler found the bacillus of diphtheria and Gaffky published his researches in regard to typhoid fever. These results were of great practical value and furnished sanitarians with a sound working basis. It was self-evident that if the bacteria were the cause of disease they must be kept out of the body. A new stimulus was, therefore, given to the study of the nature of the bacteria in food and water.

In 1885, Dr. P. F. Frankland used the Koch plate method in the examination of the water of the London filters, and even before that Koch himself had used his method in examining some of the German water supplies. Here for the first time bacteriology was made to serve the engineer. The character of a water supply or the efficiency of a filter could now be determined as never before. It must have been indeed gratifying to those who constructed the early filters in England to learn that 95 to 98 per cent. of the bacteria were being removed from the water. The results of analysis, however, showed that there was still room for improvement.

Bacteriology has shown that the terrible epidemics of cholera and kindred diseases, which in times past have swept over Europe and which have sometimes threatened to invade America, may be prevented. It has shown how the germs of these diseases are often water-borne and how essential it is for communities to be supplied with water free from any suspicion of pollution. It has shown how this may be accomplished by means of proper filtration. Filters now in operation have given practical proof of their efficiency. Perhaps no better example can be cited than the ex-

perience of two German cities during the recent outbreak of cholera.

The cities of Hamburg and Altona, situated on the Elbe river, are so close together as to be practically one. There is no natural boundary between them. In 1892, when the cholera epidemic threatened all of Europe, both cities drew their water supply from the river. The water supplied to Altona was filtered with great care, but the Hamburg filters were not completed and the city was served with raw water somewhat improved by sedimentation. The different behavior of these two cities with reference to the cholera was remarkable. We all remember how severely Hamburg suffered and how, out of a population of 640,000, 17,000 were stricken with the disease. In Altona, with a population of 143,000, there were not over 700 cases and many of these originated in Hamburg. Prof. Koch, in describing the epidemic, said, "Cholera in Hamburg went right up to the boundary of Altona and there stopped. In one street which for a long way forms the boundary, there was cholera on the Hamburg side, whereas the Altona side was free from it."

But we need not go abroad to find examples of the protection which a properly filtered water supply gives to a community against the invasion of water-borne diseases. The city of Lawrence, Mass., situated upon the Merrimac river and utilizing this polluted stream as a source of water supply, suffered for many years from autumn epidemics of typhoid fever. In 1892 the city constructed what is perhaps the most scientifically designed filter in existence.

Soon after it had been put into use, bacteriological examination of the purified water showed an almost entire absence of bacteria. The immediate and remarkable decrease in the death rate from typhoid fever after the installation of the filter, stands as a splendid triumph of modern science and as a striking example of what the sanitary engineer of the future is to accomplish.

If such results are possible in Altona and Lawrence, they are possible elsewhere, and it is to be hoped that the day is not far distant when no community will be content to be served with drinking water that has not been filtered or otherwise purified. It will sometime be considered as much an act of barbarity to drink unpurified water as to eat uncooked food. We used to hear a good deal about the theory that "running water will purify itself," and acting upon this theory it was considered safe to utilize a river both as a place of disposal for sewage and as a water supply for domestic purposes, provided that the outlet of the one was several miles removed from the intake of the other. Bacteriological studies have exploded that theory and we must now look upon the use of such a polluted water not so much as an error of judgment, but rather as a crime against the community.

For a long time to come, however, it is probable that many of our cities will continue to use surface water stored in natural ponds or artificial reservoirs without filtration. Even with filtration, storage reservoirs will be found necessary. The question of storing water is, therefore, one which must receive the

careful attention of the engineer and it is one upon which biology can offer him great assistance.

Water is never found chemically pure in nature. It invariably contains certain substances in solution which are suitable as food for some of the micro-organisms, the amount of this food material varying within wide limits. Now the micro-organisms, or their spores, are widely distributed and they are not slow in seizing upon the food supply which the water has abstracted from the soil and placed at their disposal. It is, therefore, not an easy matter to store water and be sure that it will retain its original good qualities. Scores of instances are on record where the water of ponds or reservoirs has become totally unfit for use on account of troublesome organisms. While it is perhaps unnecessary to cite examples of afflicted water supplies, it may not be out of place to refer to a personal experience with an organism hitherto unknown to be one of our enemies and seldom if ever before observed in drinking water.

A few weeks ago the water supplied to one of our New England cities was noticed to have a faint green color as it came from the tap. When a glass of it was held towards the light and examined closely, it was seen to be filled with minute particles. On standing, these particles settled out as a bright green sediment. The water had a slight unpleasant taste and odor but this did not cause much comment. On Monday, however, when people began to use the water for washing, a cry was set up all over the city that the water left green stains on the clothes. Before noon samples of stained clothing began to appear at the

office of the Water Board and it was evident that the matter needed investigation. The city takes its supply from several artificial ponds which are so arranged that they may be drawn upon singly or in pairs. At the time of the trouble the water was being drawn from the pond which has always been the worst offender in supplying objectionable organisms. This water was at once shut off and a series of samples was collected from all the ponds to locate the nature and extent of the trouble. Strangely enough the samples contained very few organisms, and the water of the suspected pond was particularly free from them. The writer, in company with the superintendent of the water works, then made a personal inspection of the sources of the supply, and was successful in locating the cause of the trouble. The water of the suspected pond, instead of being carried to the city all the way through pipes, flows for a part of its course through an open canal. At the time of our visit the water in this canal was found to be swarming with *Raphidomonas*, a minute animal form. This infusorian has a bright green color due to the presence of numerous chlorophyl grains and it was this chlorophyl which caused the green stains on the clothes. It was fortunately an easy matter to get rid of the organisms. The canal was emptied at the waste-ways, and the sides and bottom thoroughly cleaned, after which the water was again allowed to run through it. The tap water soon returned to its normal quality.

The organisms which are responsible for most of the bad tastes and odors in water supplies belong to the class above referred to as "microscopical organ-

isms." As a rule they are said to be quite uninjurious to health, but when occurring in enormous numbers, it is no wonder that people speak of them as they did in Berlin when a severe visitation of *Oreno-thrix* was pronounced a "water calamity."

It is only within recent years that biologists have systematically studied the microscopical organisms, and it is worthy of note that their study has been greatly stimulated by engineers who have appreciated their importance. From 1675, when Leeuwenhoek first observed "animalcula in pepper water," to the middle of the present century, they were studied solely from the botanical and zoölogical standpoints. Thousands of species were named and classified. In 1850 Dr. Hassall, of London, pointed out the practical sanitary value of microscopical examinations of water. His suggestions were taken up by various workers in England and Germany, but for more than a quarter of a century there was little done to perfect the method, which consisted merely in the examination of the sediment deposited from a sample of water in a suitable jar. Since 1888 the sanitary study of the microscopical organisms has been pursued with more diligence on this side of the Atlantic. Numerous improvements have been made in the methods of examination, culminating in what is known as the Sedgwick-Rafter Method. This consists in determining quantitatively the number of organisms in a sample of water by collecting them on a sand filter and subsequently transferring them in a little water to a suitable cell and counting them under the microscope. This method has been of great

service in extending our information concerning the living organisms in drinking waters, and we appreciate their importance as never before. The extensive series of biological examinations made by the Massachusetts State Board of Health, by the Boston Water Works, and by others, have been of much practical benefit. It is now known that ground water must not be stored in open reservoirs, but must be kept in the dark to prevent the growth of algae, which is almost sure to be stimulated by exposure to sunlight. It has been shown that in order to store surface water safely the reservoirs must be clean. Engineers have been a long time in coming to realize this, but it is now generally accepted by the best authorities that in constructing a reservoir it is absolutely essential to remove all the organic matter of the soil likely to be covered by the water. Biological studies have also shown that it is necessary to properly drain the swamp areas that occur within the watershed of most surface supplies, because they are active breeding places for troublesome organisms. Our knowledge regarding the seasonal occurrence of these organisms is being greatly extended, and we shall soon know better how to manage certain supplies in order to get at all times the best water possible. We are also learning which of the organisms are likely to cause trouble and the number that may be present in a water without producing bad effects.

It is not only in connection with questions of water supply that biology has been of service to the engineer. It has been equally useful in helping to solve the problems of sewage disposal. The old practice of

allowing the sewers to empty their vile contents into the nearest pond or stream is gradually being abandoned, and in its stead some form of chemical treatment or some system of filtration is beginning to be used.

Great advances have recently been made in the ideas regarding sewage filtration. It was first supposed that the ground acted as a strainer to remove the solid particles and very fine sand or loam was thought to be the most efficient material. Then it was said that the action was one of oxidation within the pores of the filter. This was nearer the truth ; but it remained for the biologist to provide the true theory, namely, that purification is chiefly effected through the action of bacteria which establish themselves in the filter upon the sand grains. The magnificent series of experiments which has been carried on at the Experimental Station of the Massachusetts State Board of Health has thrown a flood of light upon the theory of sand filtration as well as its practical application. It has been found that a filter must be treated not as a strainer, but as an immense colony of organisms whose one object in life is to convert the decomposable matter of the sewage into harmless nitrates. These organisms must be given their food regularly and in definite quantities; they must be given a certain amount of oxygen and a certain amount of time in which to do their work—these factors all depending upon the character of the sewage filtered and the composition and amount of the sand used. Properly treated, a filter will continue to do its work faithfully for a long period. It cannot, however, be trifled

with. It must not only be properly constructed, it must constantly receive the faithful attention of one who understands its nature and the needs of the bacteria which dwell within its pores.

The science of bacteriology has touched the engineering profession at other points which need not be specified. What is most important of all, it has caused a tremendous uplift of public sentiment in favor of better sanitation everywhere. Better plumbing, better ventilation of buildings, better methods of disposal of all sorts of waste material, better care of streets, are all being demanded by an enlightened public.

All this means more work and greater responsibilities for the civil engineer. He is the one who must carry out the reforms ; he must see that the work is properly designed and carefully executed. Such a man upon whom depends the expenditure of vast sums of money, and even the fate of human lives, needs to be broadly and deeply educated. In this age of bacteria he should have at least some knowledge of biology—enough to enable him to properly appreciate the nature of the problems of water and sewerage work, and to co-operate intelligently with expert sanitarians in their solution. He need not be able to make a chemical or a biological analysis, but he ought to know how to interpret one and how to make it of practical use ; he need not know how to make a pure culture of *Bacillus typhosus* or how to distinguish it from *Bacillus coli communis*, but he ought to know how typhoid fever is transmitted and what measures should be adopted to protect a community from its ravages ; he

need not know the names of all the micro-organisms and their proper classification, but he will find it of advantage to know the characteristics of the most troublesome forms that occur in drinking water.

In ordinary practice, cases frequently occur where the engineer is obliged to act promptly and upon his own responsibility, and where even an elementary knowledge of biology would be of material assistance to him and enable him to avoid serious mistakes. It would also serve to prevent him from being unduly influenced or alarmed by the sensational utterances which are continually appearing in the public press in regard to "the deadly germs." As an illustration of this we may refer to an epidemic of typhoid fever that occurred not long ago in a city not far from Boston. The increasing number of cases caused the usual alarm and the usual number of wild speculations as to its origin. By some of the leading physicians it was attributed to the water supply, and the water-works officials were much disturbed by it because they were not able to disprove the assertion. For several days they sat upon the anxious seat, when an expert biologist came and easily demonstrated that whatever else might be at fault, the water supply was above suspicion. Soon afterwards a certain milk supply was found to be the cause of the epidemic. If the local engineers had had a better understanding of the theory of the transmission of disease, they might have saved the citizens several days of anxiety and complaint.

A general knowledge of the principles of sanitary biology can be acquired by the engineering student in

less time than might be supposed. A brief course of say a dozen exercises might well be arranged to cover the ground and give the student a firm foundation upon which to base subsequent reading and study. Such a course ought to form a part of the instruction given in every college of civil engineering. This will not transform the engineer into a biologist nor is this result to be expected or desired. It ought, however, to teach him to look at sanitary problems from the right point of view; to put him, as it were, in the right mental attitude; to enable him to think in biological terms. This attitude of the mind which will be unconsciously forced upon him cannot fail to be of value not only to himself, but to the community.

But some one says "What chance is there for a course in biology when the curriculum is already full to overcrowding? What is there in the present list of studies that can be omitted or even abbreviated?" This is no doubt a serious question, one which is continually arising, and which must ever occur as long as the world advances. The writer does not feel called upon to solve it, nor to argue the relative merits of the different sanitary studies in an ideal course of civil engineering. He simply wishes to emphasize the fact that the study of biology should have its place, and should on no account be omitted. The study of principles must take precedence over the study of facts. The knowledge of general laws is higher and of more importance than the knowledge of rules. Are not the principles of sanitary science important to us all? Who needs to understand them more than the civil engineer?

In most classes of engineering students there will be found a few men (always a limited number however) who intend to devote their attention solely to sanitary matters, or as we say, to sanitary engineering. These men need a more particular knowledge of the micro-organisms than do those going into general practice, and a more extended course than the one referred to must be provided. In this course the student should be taught the history of sanitary biology, both as a means of broadening his education and as illustrating various solutions of problems which he is likely to meet. He should be made to understand the ordinary methods of bacteria culture and the characteristics of the bacteria commonly found in water and sewage, and the most important pathogenic forms. Moreover he should have some knowledge of the infectious diseases from the medical standpoint. He should understand the use of the microscope and become experienced in its manipulation. He should become acquainted with the new methods of microscopical examination and be able to identify the common organisms found in drinking water and the tastes and odors which they produce. He should be taught to study the cause of their growth and the effect of light, heat and aeration. This instruction cannot be given by a lecture course alone. To be of real value the lectures must be supplemented by actual work in the laboratory where the organisms may be seen face to face. Moreover in the laboratory the student has opportunities for original investigations and he should be encouraged to undertake them, for the field of sanitary engineering offers some of the most interesting problems of modern science.

As was said above of the general civil engineering students, so we may say of the men taking a sanitary option, that they need not by reason of this study of biology become biologists. The services of specialists in this department of science will always be needed, men who devote their whole attention to the organisms themselves, their habits, their modes of life and the conditions favorable or prejudicial to their growth. By laboratory experiment they must learn to control the micro-organisms and make them the servants rather than the masters of mankind.

In conclusion I desire to say that, while I emphasize the importance of the study of biology by civil engineers, I do not wish to underrate the value of chemistry or to overlook the part which that noble science has played and will long continue to play. Chemistry is just as valuable to the engineer as biology. The two sciences must go together hand in hand. The future triumphs in sanitary engineering, are to be achieved by engineer, chemist and biologist working together. The coming man in sanitary engineering is he who, thoroughly versed and experienced in engineering, has also the ability to use the knowledge of the chemist and the biologist.

DISCUSSION.

PROFESSOR ROBERT FLETCHER thought that all would agree that this is a subject of prime importance to the civil engineer. It is doubtless realized that one of the notable expansions of the course of civil engineering within the last five years even, has been in this direction, and teachers interested

in the general subject of civil engineering have probably given it some attention, and have called the attention of students to the results of the researches of the Massachusetts State Board of Health and of those of the Franklands, and others in Europe. There should be general agreement upon this point, and it would appear that it is in this direction especially that the enlargement of the scope of civil engineering education may well proceed, certainly as one important development.

PROFESSOR G. W. BISSELL wished to state in this connection that his colleague, the Professor of Civil Engineering, gives to his seniors a course of lectures on sanitary engineering. It is a course of about thirty lectures, given in the first term of the senior year, in which, in addition to a few lectures on sanitary plumbing and mechanical details connected therewith, a large number of lectures are given upon the subject of the purification of sewage and of drinking water supplies, according to the most approved methods, and describing in connection therewith, tests which must be applied for the detection of impure water and the mechanical expedients to be used in connection with the correction of impurities. At present no biological laboratory work is done in this connection.

AN EXPERIMENT IN THE CONDUCT OF FIELD PRACTICE.

BY FRANK O. MARVIN,

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The writer does not claim any special originality for the plan or methods of work here outlined, but has thought that it might be well to state some of his experience, desiring to contribute his mite in return for the many hints received at former meetings of this society.

For several years the engineers' field work at the University of Kansas was confined to term time. The desultory practice of a few hours at a time in the midst of other routine work, even when supplemented by a half day on Saturdays, did not secure satisfactory results. Three years ago, a requirement of one month's continuous summer field work was added to the course in civil engineering for each of the three lower years, Freshman, Sophomore and Junior.

So far, the time has been given to topographical work largely, though a little railroad work has been done, and one party for one season spent the time on a line of precise levels. The students were divided into parties of three each, a Freshman for rodman, a Sophomore for instrument man, a Junior being put in charge, or rather this was the plan. As it has worked out, some parties have been in the charge of Sophomores or Seniors. Each party has been given some certain square mile of which it was to make a full topographic survey on the basis of five foot

contours, it being also required to show buildings, land lines, character of cultivation, timber, etc. The sections taken by the different parties joined, with the camp located near the center of the territory occupied.

The month's program consists of about two days of reconnaissance for triangulation points, so chosen as to tie the work of all parties together, with lines from one half mile to two miles long; three days in the reading of angles, using both a Fauth transit reading to ten seconds, and a Fauth altazimuth reading to single seconds; two days of leveling between triangulation points, with check lines; ten to twelve days of stadia work with about 500 side shots to the square mile, and three days on notes, using a Colby Slide Rule for reductions, and on a field plat on a scale of 400 feet to the inch. A base of 3,000 to 4,000 feet is measured with a 500 foot tape and observations are made for azimuth.

The triangulation net has not been solved in camp every year. In the fall term each party makes a final plat on a scale of 250 feet to the inch.

The students plan their own work and make their own checks, finding their own errors so far as possible. An instructor and assistant are in general charge and are ready to help out of difficulties, giving their time to the different parties as they may need it; but the students are made to feel their responsibility in the conduct of the work. The head of each party, especially, learns very soon that the character and progress of the work depends on him, and there naturally arises, as the work goes on, a pride in getting good checks and in keeping well up with or even ahead of

the others. For the first few days some young men have needed a little urging, but the necessity for that disappears after the work is well under way.

There are two objects governing the choice of this method for summer work. The chief consideration is the educational one. The topographical survey is used firstly, because of the variety of its different steps ; reconnoissance, putting up and maintaining signals, leveling, transit and stadia work, angle reading, sketching, the use of the slide rule, base work, adjusting instruments and standardizing rods, solar work, adjustment of observations, platting ; secondly, because so small a number of students can constitute a party. The instrumental practice and all the details of the survey get hold of *each* student to a greater degree than is possible with any other form of survey. The Freshman, who knows nothing of surveying at the beginning of the month, learns much about instruments and details of work. He knows what it is to cut underbrush, drive stakes, put up poles, to carry a stadia rod ten hours a day, and, not least by any means, he learns to take orders and to obey. Moreover, about camp, his natural inquisitiveness turns his chief into a teacher who initiates him into the mysteries of instrumental construction or method. The men that have been in camp can be readily picked out from the members of the class in surveying that comes regularly in course in the Sophomore year.

When the student, a year later, takes his instrument or his party, he knows how to give orders, for he learned how to take them the year before. He knows in a quite definite way what is expected of his

party, and he tackles the problem of his own ground confidently. Within a couple of days he has the entire work planned, knowing where he expects to place his triangulation points and how to run his stadia traverses. He may subsequently change these to adapt them to the work of other parties. He may not always make the best locations and choose the best lines, but he generally finds out how they could have been bettered. The essential point remains that the work is his own.

This placing of responsibility on the young men acts differently with different temperaments. It strengthens the timid and checks the carelessness of the overconfident. The hasty man is brought up short by a traverse that will not check out, or even agree with itself on a second trial, and may be inclined to lay all the trouble to the instrument. But when he finally makes a good line with one minute's error in azimuth and a tenth or two in elevation, his respect for his transit is augmented at the expense of his estimate of his own ability. These blunders, and they are numerous every season, are not the least valuable means of instruction. A student will gain more from them, both as to technical matters and as to character, than from a system involving too close supervision on the part of the instructors. Not every error is found by the student, but often it needs only a question from the instructor to open up the way for its discovery and it is rarely necessary for him to make a complete investigation of notes or to re-run a traverse.

The comparison and weighing of the relative im-

portance of errors, and adapting checks on the several parts of the work to the character of it as a whole, proves a good exercise.

This continuous practice also brings the student into contact with the little difficulties connected with instrumental work, the moods and whims of his instrument, as well as its permanent peculiarities. He finds out about the run of tangent screws, the clouding of glasses, the effect of a hot day on centers and takes the thing to pieces to find why the verniers will rise above the plate. There are many items, not learned in the class room or the ordinary field practice, that come to him through his own work or through the conversation about camp. Some may think it unsafe to trust instruments to the hands of the students to the extent here used, but the writer has had no trouble. The students understand that they will have to pay for the result of any carelessness on their part, and this has been a sufficient safeguard.

Another advantage of the plan is the close association of instructors with students of different classes in the jolly camp life. The camp outfit, by the way, is a good one, with heavy duck for tents, cots for beds, a stove, and plenty of tinware. Being permanent for the month, there is no expense for teams except at the beginning and end, and as the University furnishes the incidentals, the cost to the student is limited to the table requirements, \$10 to \$12. The camp life proves healthful and adds a little spice to the serious work that fills ten hours of each day. If an area of more than five or six square miles was to be covered, either

the employment teams would be necessary, or the camp should be divided, the latter being the better plan.

According to the writer's experience, one instructor can handle at least four parties, provided the head of each has been out at least one year before.

The second reason for choosing this particular plan was a desire to obtain the data for a topographical map of the country immediately surrounding the University; this had a rolling surface, broken by large streams and bluffs, was about two hundred feet high and well adapted for instructional purposes. It was further thought that students would take more interest in the work if it had some object other than the giving of instruction.

Most of the ground covered in the three years has been or can be platted. One or two parties did not have time enough in the month they were in the field to untangle all of the snarls they got into, and as the camp is shifted each season, there has been no opportunity as yet to fill in these gaps. The work of the students is variable, with errors of azimuth ranging from nothing to several degrees, or from a tenth to several feet in elevation. But with the lines of a mile in length corrected to within five minutes of azimuth, and a maximum difference between the level and stadia elevations of a half foot, with the former checked upon themselves within a tenth or two, good maps showing five foot contours can and have been made; and where the work of different parties has been adjacent it has joined well. In angle reading, better work has been done with a transit reading to ten seconds than with the altazi-

muth reading by micrometers to single seconds, or tenths by estimation. Yet it is thought wise to use both. The base work has been variable; no special pains, so far, have been taken to secure high grade results, although one season's base, measured along a railroad tangent, represented an accuracy of over one in 100,000.

The nice theory of having a Junior in charge, a Sophomore at the instrument, and a Freshman for rodman, does not work out in practice. The chief difficulty is the desire or necessity on the part of so many to earn money during vacation. When students do such summer work in engineering in actual practice, they are given credit against the required field practice. Again the men are well satisfied to put two summers into topographic work, but not all of them a third, and in the main they are probably right. So in the future the third year may be spent on something else, or the work of the three years may be made to rotate about three classes of work, topographic, hydrographic, and railroad.

There is no question, however, as to the value of the topographic survey, conducted as above, in teaching field methods and developing character. The practical working knowledge gained and the traits of mind cultivated are along the line of the young man's needs, when he takes his first position.

It must not be inferred that the above constitutes all the field work required at the University. General surveying, railroad work and hydraulics are cared for in other ways during the college year.

DISCUSSION.

PROFESSOR E. A. FUERTES said he had been very much interested in hearing Professor Marvin speak of the use of this method, which, the speaker had found from experience extending as far back as 1874, to be most excellent. Cornell University has adopted a similar practice, although it varies somewhat in detail; and the reason for speaking of it is not at all for the purpose of comparison, but simply to present a new aspect of the case, so that everyone may profit by the variety of solutions of which these kinds of experiences are capable. At Cornell, the students are not taken out during the summer vacation for the very good reasons given by Professor Marvin; generally, many of them need the summer to earn money. Their work is, therefore, confined to two weeks at the end of the junior and senior years. Some of the work done is of a character high enough to be beyond the reach of freshmen and sophomores, who are given field practice on the campus on afternoons and Saturdays. Usually, from sixty to eighty juniors and seniors take the field, and they generally get through with about 144 square miles of territory. Their operations are similar to those performed by a large corps employed for the surveys of international boundaries. There is a chief engineer chosen by the students. The object of this is to enable the students to come in contact with the person who has the actual lead in the operations to be performed; for a good deal of information can be gained, and more intimately, from a classmate than by asking the professor, whose

relations to the student are of a more formal nature. In order to prevent a bad choice under the usual influence of class politics, the college appoints the Computer. This officer is responsible for all the checks of the mathematical work, and of all the operations of the survey. The students also choose a Commissary. This Commissary has the responsibility of providing for and maintaining the parties in the field, paying in cash for every purchase and incurring no debts. The Commissary looks after the health and comfort of the students, and so on. This is also a very good sort of experience, and something which the students appreciate, for they all learn, by student contact, the best methods of subsisting a large party in the field. Besides the assistant chief, and the assistant commissary, the rest of the officers are captains. The parties are divided into squads, each one being placed in charge of a captain. These captains are usually chosen by the college from among the men having the best record, taking into account their previous field experience, their executive capacity in the handling of men and making the work run smoothly. The surveys are in charge, of course, of the chief engineer ; but certain parts of the work are confined to the seniors, others to the juniors. The seniors first make a connaissance of the country and locate the primary stations, so as to get the work ready for triangulation. The triangulation is made under the very best auspices ; so much so that the final adjustments of the net of triangles agree, within proper limits, with the measured base lines, as well as with the azimuths determined by other surveys or astronomical observations of tri-

angle sides of the net. The juniors have the topography. The base line is first measured with a tape, and afterwards with the base line apparatus made by the Coast Survey and improved and compared at the college. One end of the base line is usually made an astronomical station, from which the latitude and longitude of the place, and the azimuth of the base are determined. The primary stations are made the starting and ending points for all topographical work. The seniors only have charge of the astronomical, geodetic, hydrographic, gravimetric and magnetic work. The lakes of Central New York are generally selected, for they offer, providentially, a fine country for this sort of work. They represent a variety of surface, and difficulties and advantages of all kinds for studies of this nature. In the topographic work of the seniors, the distances are measured with the stadia. It has been found impracticable to do otherwise, since the triangle sides vary from one or two to twelve miles, and all errors of measurements are balanced between primary stations. Secondary stations are located with much care, for they are often found in the shores of the lakes, and serve as the starting points of lines of soundings.

The advantages derived from this experience are incalculable. In the first place the young men enjoy it heartily. They work from about seven o'clock in the morning, often until past midnight. It is wonderful to see what a large amount of work students can do under these conditions. They lose weight, but gain in strength, health, and buoyancy of spirits. This work has been going on at Cornell for the past twenty-

four years; and, aside from the University of Kansas, the speaker knew of no other institution where a similar method has been pursued with the same or an equivalent organization. Few portions of a college course are as suitable as these surveys to develop in young men self-reliance, independence, versatility of resources, the solving quickly of difficulties, and the art of learning how to obey, which is possibly one of the hardest lessons to learn; the man who cannot obey will never be able to command.

The speaker desired to give the floor to some one else; and would end by adding that he would be glad to mail to anyone a pamphlet containing the "Field Instructions" used by the Cornell engineering classes, if any of the professors present should be willing to take the trouble to write for them.

PROFESSOR M. E. WADSWORTH wished to speak about a point which does not affect the method of Professor Marvin as presented, nor the one Professor Fuertes had spoken of, but which simply describes an attempt to solve the question of field work in surveying in a special situation. Every institution must have its own methods. At the Michigan Mining School the question that presented itself to the institution at first, was some method of taking care of the practical as well as of the theoretical work. Also, in the time that was allowed the student, to give him an amount of experience that would enable him to apply his knowledge after graduation. That is, while he might know the theory, if he could not adjust his instruments and practically meet the different problems likely to come before him, his previous study was

worthless to him until he had learned later, by practice, how to apply it. The question was solved in this way: The ordinary summer vacation work is by most students taken as a vacation, a general good time; they do the work when they are compelled to, but they will not do it well unless absolutely obliged to. The failure of the summer school to impart real instruction becomes strongly marked if there happens to be in charge of it an instructor who is what students term "a good fellow," but who has no idea of real discipline or systematic instruction. The method that the Michigan college employed was this; all of the practical work was put in the regular year, or made part of the regular system. Thus the student's work in the summer time is as much a constituent part of the school course as it is in the winter term. To do this the regular school year was increased to 45 weeks. In the field surveying, the practical work covers various different subjects, like plane surveying, topographical work with stadia and plane table, geodetic work, railroad surveying, etc. The practical work in surveying, exclusive of mining surveying, occupies eleven weeks of the year, nine hours a day for five days a week; Saturday is taken usually in making up for the rainy days, for draughting, for making up back work, etc. The extra day is needed by many of the students, for while some are rapid workers, others are slow. The student in the field, in his surveying, is under the ordinary drill and discipline of the school, and he is made to work just as a young surveyor is required to work when he commences his practice subsequent to graduation. The

instruction in theoretical surveying has, heretofore, been given during the fall and winter terms. That has been found to be disadvantageous, owing to the fact that the student forgets the theory before he has time to apply it. Consequently during the school year 1896-7, the theoretical instruction will be given in connection with the field work of eleven weeks; that is, the student will hear the lectures and have his recitations in the morning at eight o'clock, going into the field immediately after, and applying the principles directly in practice.

PROFESSOR C. F. ALLEN remarked that one point was suggested to him by reason of something that Professor Wadsworth said: the speaker had just a bit of doubt as to the advisability, or as to the necessity of always setting the men at their field work while the class work is fresh. The field work is better done at that time, and yet it is not sure but that the student is better off if his field work in some subjects comes in the way of a review of his class work. In certain parts of the work nothing suited the speaker better than to get hold of the men when they had forgotten all about the subject in hand. Take them without warning, put them at work on something where they cannot use a book of tables, where they have no opportunity to get at their formulas, but where they must derive them, and let them do the work at a time when the whole thing has been laid aside and when they are not expecting it. The work that the men do in that way is work that is much more likely to stand by them than work that they do under any other circumstances. If you can put a stu-

dent where it is absolutely essential that he shall use his thinking apparatus instead of his memory, you have done a wonderfully good thing for him. It is very hard oftentimes to do this. At least one student more than twenty-five years of age who had spent more than two years in a prominent technical school, was very much surprised at the idea that the thing for him to do was to use his good sense instead of his memory, and this in work essentially geometrical.

PROFESSOR WADSWORTH explained that he believed all that Professor Allen said in regard to the value of practicing students in surveying during the later portions of their courses; but in the case of the Michigan Mining School the mining surveying, which is done underground in the mines in the spring, requires that the plane and railroad surveying preparatory to it shall come during the preceding summer. Further, since the mining surveying is preliminary to the mining engineering, the order in which the three subjects naturally fall is as follows: First Year: Plane and Railroad Surveying, Principles of Mining; Second Year: Mining and Mine Surveying, Theory and Practice; Third Year: Mining Engineering, Mine Managements and Accounts.

CREDIT FOR SHOP EXPERIENCE IN ENTRANCE EXAMINATIONS.

BY WILLIAM T. MAGRUDER,

Professor of Mechanical Engineering, Ohio State University, Columbus, Ohio.

Within the past year, a circular, descriptive of the mechanical engineering course of one of our Eastern universities, has unintentionally stirred up a discussion in the technical press on the "Admission Requirements in Engineering Schools." The first editorial on the circular was followed by no less than twelve letters from correspondents, requiring two editorials and seven editorial answers. The editorial in question sought to call attention to the fact that some of the best material for mechanical engineers was to be found among the artisans of the shops, who, having had but a common school education, were unable to pass the entrance examinations of our engineering colleges and acquire a higher technical education; that the schools should accept the shop experience of the young artisan as an equivalent for the mathematics, or other subject required for admission, in which the young man was deficient, giving him credit for the same in the prescribed course; and that they should also devise means by which, while making up his deficiencies, he could pursue the regular course and graduate with the class. The real intention of the editorial does not seem to have been perceived for two months; and as it is a criticism of the mechanical engineering courses of all our colleges, the writer suggested it as a fit subject for discussion at this meeting of the society.

Four plans were suggested. First, that all "applicants be required to have served an apprenticeship in a machine shop." Second, that "shop experience and a good grammar school education should be the only requirements for admission to such a school." Third, "that the arbitrary division of classes and the iron-clad courses of the past be entirely abolished, and an elective system of studies be substituted, and the student left free to choose such a line of work as would best enable him to develop his talents, and prepare himself for the future he had in view." Fourth, "that previous shop experience should offset some of the more advanced of the present requirements, the time which the present class of students devote to shop-work being given by the new class to the preparatory studies in which they would be deficient."

In order to discuss this subject profitably and intelligently, there must be some common ground from which to start, and as the writer cannot agree with several of the correspondents above referred to, he will establish his own position by stating that, in his opinion, the object of the engineering courses in our technical schools is, first and foremost, to educate young men in the principles of the profession of engineering, rather than to train them in the details of some engineering process, to make engineers and not artisans; second, that the technical college of to-day is in no sense a trade school, the relation of the one to the other being similar to that of the law school to the business college; and third, that it is an erroneous idea, although it seems to be current, that the State University owes every man an education in

some of its courses, no matter how inadequately supplied he may be with brains and means, or how poorly prepared to take such a course. Furthermore, the opinion seems prevalent that the reason for the existence of engineering college shops is to take the place of the apprenticeship system; and that the young man who has served his three years at one trade has more than the equivalent of the amount of knowledge possessed by the young man who has been educated in the shop-school in the principles and technology of almost a dozen trades, who has been trained in the school-shop in the use of the tools of those trades so as to learn something of the speed, capacities and capabilities of those tools, and to apply the principles learned in the school to the practice in the shop, and who has also gained a practical knowledge of how different materials can be used and worked. With this idea the writer cannot agree.

In order to secure definite information as to what is the current practice of the mechanical engineering colleges of the country in regard to giving credit for shop experience, the writer addressed a circular letter to the head of the department in some eighteen of our largest technical colleges, and received seventeen replies, for which he desires to publicly express his gratitude. From these replies it appears: First, that, instead of upward of sixty to seventy per cent. of all mechanical engineering students having had shop experience on entering college, as was the opinion of one of the writers, the average is less than five per cent. At Cornell and at the Massachusetts, Stevens, and Worcester Institutes, probably as many as ten per

cent. have had some experience, but only five per cent. have served their time or done enough to count for anything; while at the Virginia Polytechnic Institute as many as twenty per cent. have had shop experience. Second, that machine shop and pattern making are the more commonly offered trades; carpentry is seldom offered; wood-turning, joinery, moulding and founding, pipe-fitting and the like, are never offered. Third, the common practice seems to be to examine the young man in the shop on exactly what he can do with tools, and require him to execute with his class those exercises of the shop course in which he is deficient. At some of the schools, certificates of having been a manual training scholar, or of having worked one year in a shop, is sufficient to excuse him from that subject. As manufacturing shops differ among themselves, especially in the amount of instruction and variety of work they give their boys during the first year, this does not appeal to the writer as being a safe rule, nor does it seem to be setting much value on the school-shop training. In no reply is any mention made of the requirement of certificates or examinations on the amount of knowledge possessed as to the technology, speeds and shapes of tools, their methods of use, or to shop-school training. Fourth, as to whether passing a man on shop work on certificate or after examination has proven satisfactory, the result depends largely on the care and thoroughness of the examiner of the certificate and of the student. In a number of cases, it is reported as not being as satisfactory as the regular shop course. Fifth, in answer to the question asking

what special inducements are held out to experienced mechanics to take a course of study, the almost invariable answer was "none." The exceptions were that in several State Colleges, men over twenty-one years of age are allowed to try the course on their own responsibility and without any examination. At Stevens, the "dropping of French and Spherical Trigonometry was done with a view to attracting such students." At several, students who are experienced mechanics are allowed to pay their tuition fees and to earn money by their labor. In only two is any mention made of allowing shop work to be offered as the equivalent of language or mathematics, and nothing is said as to what course the student pursues who has never studied Algebra and Geometry.

There are three classes of applicants for credit for shop experience in entrance examinations: the boy from the Manual Training School, the boy who has worked in a shop under instruction before taking his intended technical school course, and lastly, the young man who has served his full time at one trade or has partly done so. The first class may form as many as twenty-five per cent in some of our Eastern schools, but for the entire country will average nearer five per cent; the second class will average less than one per cent; while the third class, as has been shown, will probably average less than five per cent. It is not a question of giving just credit for work already performed, but the rather of making such changes in the existing courses as will accommodate those persons who might become applicants, and make good engineers.

Let us now return to the four plans proposed by which the young artisan who, deficient in mental training, is to square himself with the other members of the class. To require all applicants for admission to our mechanical engineering courses to have served an apprenticeship at one trade is to throw a burden on the trades which they do not seem to be disposed to carry for their own salvation, let alone for philanthropy's sake. It is also going on the assumption that one trade, presumably the machinist's, and only to the extent of the three years of an apprenticeship, is all that the mechanical engineer needs to be acquainted with.

To reduce the requirements for admission to "shop experience and a good grammar-school education," would be a long step backward and downward, and would lengthen the present courses by at least two years.

To introduce the elective system may solve the problem, if the faculty, or one of its members, do the selecting of the work for each student according to his preparedness. This is the practice of many schools at present with irregular and special students, and requires much foresight and firmness on the part of the adviser. To let the young student be his own director, and to let him decide what course he shall take to prepare himself for what he thinks is engineering, is to introduce disorder and to put a premium on ignorance, and to require a much larger teaching force. In a recent case, the young man selected steam engineering, machine design and the like, and left out the calculus, analytical mechanics, and allied subjects.

His idea was that mechanical engineering was a trade which would teach him how to build and run engines. He had not yet grasped the idea of designing, except as a rule of thumb founded on experience.

In the opinion of the writer, the engineering colleges would benefit themselves and the profession by offering special inducements to men who had served their time in the shops, by mapping out a course and arranging a schedule by following which they could reach the coveted goal. In the case of State institutions, such a schedule can probably be formed from existing courses in the university, or, if necessary, in conjunction with the nearest high school.

The observation of the writer has been that some of the best and most successful mechanical engineers, and this applies also to teaching engineers, are those who have had the largest experience in the shops and drawing room in actual constructive work. Second, that those schools are growing most rapidly which have the shop-course most fully developed. And third, that the number of mechanics who are applying for admission to our engineering colleges, and who are anxious to take a full technical course, though small in numbers at present, is rapidly increasing.

If, without lowering the standard required for graduation, many men can be added to the profession who are well endowed with mechanical skill and engineering sense, though deficient in early mental training, is it not the duty of the technical schools—at any rate of those institutions receiving governmental aid—to make the path of such young men straight and plain?

DISCUSSION.

PROFESSOR STORM BULL said that he had been very much interested in this paper and in a conversation with Professor Magruder before the paper was read. He knew that the one letter which did not receive an answer came to the University of Wisconsin. That is one of the reasons why the speaker wished to say a few words in reference to the mechanics who like to come to the University. The institution with which the speaker is connected is one of those in which mechanics are received on special conditions. They must, at least, have served their time ; they may, for instance, have spent three or four years in some machine shop ; they are received without examination ; that is, if they can show conclusively that they have sufficient knowledge to follow the courses offered in the University. In order to follow the courses in engineering, in machine design, in steam engineering, they must have mathematics ; that is, it is necessary for them to have algebra and geometry, subjects which are not taught at the University. If they have this knowledge, then they are allowed to take studies which they are capable of following, but they are not allowed to graduate except by making up the studies required for admission. The speaker had had considerable experience in this line, and a large majority of the students admitted in this way turn out very well. Quite a number have graduated after having made up the requirements. They must make up their language studies ; they must make up their physics and chemistry, and whatever else is required

for graduation. It would not do to lower the requirements for graduation in any line. When a student is graduated, a kind of a stamp is put on the man which means that he has pursued a certain amount of study and that he has passed an examination in all those lines which are required for admission. The three years which Professor Magruder mentioned, occupy the place of four years in the West. Four years in Allis' shop in Milwaukee means simply an apprenticeship. The speaker knows of three students who had served their time at Allis', and who had graduated later from the University; they have turned out very well. The speaker appreciates the fact that a machinist who has worked four years at the machinist trade does not necessarily know very much about moulding or pattern making, and so it is not customary to give him credit for full shop work. A student is given credit for the amount which has been accomplished; if he is a machinist, he is given credit for that class of work, but he must go through the moulding and pattern making.

IS NOT TOO MUCH TIME GIVEN TO MERELY MANUAL WORK IN THE SHOPS?

BY W. H. SCHUERMAN,

Dean of Engineering Department, Vanderbilt University, Nashville, Tenn.

The question forming the title of this paper was one which the writer could not help asking himself while going through a mechanical engineering machine shop and noticing the kind of work that some students were doing and had done, and which seemed to him to require the expenditure of much more valuable time than the benefit derived justified. The subject of shopwork has been treated at previous meetings of this Society, directly in two papers (See Proceedings, Vol. II., p. 206 and Vol. III., p. 126) and incidentally in others and in discussions (See Proceedings, Vol. II., p. 243 and Vol. III., pp. 56, 270, 300). Professor Marx's paper at the Brooklyn meeting was, for want of time, read by title only and it was with the hope of obtaining more views on the subject that the preparation of this short paper was undertaken and the title put in the form of a question.

It being conceded that it is not an object of technical education to make mechanics or artisans, it does not seem to the writer that manual work in the shops should stand on the same plane as, or be considered of equal importance with drawing, laboratory or field-work, as has been contended by some members of this Society. The engineer will himself have to use some, if not all, of the instruments of the drawing room, laboratory and field, in his later practical experience

and can not be too expert in their use; whereas if he can be considered at all successful as an engineer, he will himself have to use hand and machine tools very little, and time spent in acquiring a high degree of facility in their use might have been much more profitably occupied by other subjects. All attempts to arrange an engineering course of study show conclusively that the great difficulty is to find enough time in four years for all the studies and work that are considered essential.

The principles and methods involved in forging, molding, pattern-making, casting, rolling and ordinary machine work should be understood by the civil as well as by the mechanical engineer, but few having in charge the arrangement of a civil engineering course would consent to give as much of their limited time to manual work in the shops as some of our mechanical engineering colleagues seem to think necessary in order to acquire sufficient knowledge of these subjects. Instruction in them should in large part be given in the class room, using as a text something like the first part of Lineham's Text-Book of Mechanical Engineering and restricting the work in the shops to what is necessary for impressing principles and methods on the mind of the student, and avoiding all that would simply increase his manual dexterity. Very little manual work at the bench and forge, in the wood shop and foundry, is believed to be absolutely necessary, and work in the machine shop should be only carried to the point where the machine itself really begins to do the work—in other words machine shopwork should be limited to what Professor Spangler designates "laboratory work

with shop appliances." With this amount of shop-work, it would be impossible for students to make constructions themselves according to their own designs, but the writer believes that all benefits which can be derived from such constructions, except manual dexterity, can be obtained with much less expenditure of time by having the work done outside of the school-shops and, as far as possible, under the supervision of the student. He might describe fully the methods he would use in construction and compare them with those of a good mechanic; in this way he might really derive greater benefit than by carrying out the design himself. When work is done outside, proper blanks should be filled out, showing the amount of time taken in constructing each part, in order to give the student some data by which to estimate the cost of labor on different kinds of work.

One important claim made for manual work is that it cultivates the perceptive faculties and trains the hands and eyes. It seems to the writer that this can be better accomplished and with much more lasting benefit to the student by a thorough course in free-hand drawing. By making free-hand sketches of machines in commercial establishments, putting on dimensions as estimated by the eye, and checking the estimated dimensions by actual measurements, the student may approach in ability the engineer who, according to Professor Flather (Vol. II., p. 116), "in several instances comprehended the details and dimensions of a machine so completely by inspection, that he was able to make working drawings and to duplicate the machine without making a single measurement or detail sketch."

The writer does not undervalue the benefits to be derived from manual work ; he simply contends that, owing to the limited amount of time at disposal, all work of a merely manual nature should be eliminated from the courses in a technical college, and manual training, if deemed essential, should be regarded as a preparatory subject and required for admission. If a technical college be so situated that the majority of those entering have had no opportunity for taking a manual training course, a summer school might be established, in which such deficiency could be made up.

According to Professor Storm Bull, no shopwork is required in the German technical schools, and it may be of interest and value to give here the amount of time for shopwork deemed advisable by such members of the Society as have expressed an opinion. Professor Marx would allow three periods of two hours each per week for four years, equivalent to twenty-four hours per week for one year; Professor Spangler, twelve to fourteen hours per week for one year for shopwork proper, as distinguished from "laboratory work with shop appliances;" and Professor Benjamin, five hours per week for two school years, or ten hours for one year, for those who have had a course in manual training. The writer prefers about half of Professor Spangler's estimate, in addition to class room instruction and visits of observation and inspection to commercial establishments.

DISCUSSION.

PROFESSOR M. E. WADSWORTH said that it seemed to him in listening to Professor Schuerman's paper that

the ordinary manual training which was referred to in it is the work that is done in most schools by boys of the age of 15 or 16 ; while the shop practice of engineering colleges, properly speaking, is more apt to be done by young men of more mature age, and is a work of a different grade and character. For ordinary manual training, the speaker could see no objections to the author's recommendations.

He wished, however, to give the experience of the Michigan Mining School in handling shop practice for students of engineering, averaging 21 years of age and upwards. The speaker did this in the hope of bringing out the practical experience of others in like work.

At the Michigan college, the shop practice is considered to be of great value and use. The mining engineers have many occasions to use their knowledge of shopwork in the mines and about their plants. The graduates frequently express themselves strongly in favor of this work, as something that has proved very useful to them in their subsequent practice.

In order to take the shop practice and receive any credit in it at the Michigan college, it is required of every student that he shall have previously completed the requisite work in geometry, algebra, plane trigonometry, mechanical drawing, physics, general experimental chemistry, and the properties of materials.

The time given to the shopwork is eleven weeks during the summer term. It occupies nine hours a day. Five and one half weeks of the eleven are given to practice in wood-working, and five and one half weeks to metal-working. The class is divided

into two sections which alternate ; that is, one half of the class works for five and one half weeks in the wood shop, while the other half works in the metal shop.

The preliminary practice in learning to handle the tools takes only a few days for the average student, usually two. After this introductory work, the time is spent entirely upon material that is to be used in the institution, *i. e.*, upon work which is of practical value.

The shops are conducted upon the principles in vogue in outside shops, and the student is made to understand clearly the value of time, material, and quality of work done. Close record is kept of the time spent on each job, and any work which fails to pass inspection is promptly rejected. If any of the material has been destroyed by defective work, the student is required to pay the full value of the stock used up by his carelessness.

Experience shows that the students have a deep interest in their shop practice, because they feel that they are making something that can be used. In this way they receive the same mental training that comes in actual practice in planning and arranging work for their own or for commercial uses.

Lectures are given to the students upon the work and its principles, text-books are studied, and recitations are required, the same as is the case in the other departments of engineering.

After the shop practice has been completed it has been found by experience that it is of practical use as a preparation for more advanced subjects, like engi-

neering design, metallurgical design, machine design, mechanical engineering, electrical engineering, laboratory practice both in mechanical and electrical engineering, ore dressing, etc.

The speaker would be pleased to learn of the practice and customs of other institutions, and how their instructors handle shop practice. Also whether or not the work has been found to be of vital interest and of real use to the students.

PROFESSOR L. S. RANDOLPH thought the subject one of a good deal of interest. He was at present engaged in gradually changing the course. His own experience in such work was acquired where rather more time was given than the author specifies. The speaker gave ten hours a day every day in a week for about three years. But in taking charge of the shop course there were given at first, three hours a day for three days in a week throughout four years, but machine work was soon dropped out of the Senior year, then from the Sophomore year, so that now it covers only two years. There is a course in wood working, where the men are instructed in turning, making joints, dove-tails, and the like, that takes about nine hours a week for half a year. The rest of that year is given up to forge and foundry work, the forge and foundry together taking nine hours a week for the half year. That accounts for the Freshman year. In the Junior year comes the machine work, and here there has been difficulty in getting from the students the proper amount of work. The course is carried on, not so much to impart manual dexterity, as to familiarize the student with the different operations. In machine

work, they have turning, planing and boring, with different metals, cast iron, brass, and wrought iron, as well as milling and the use of different simple machines, shapers and the like. It is proposed also to bring in the subject of emery grinding and to introduce certain processes, such as the making of bits, turning out a hole and fitting a bolt into it, to show what can be done in such ways. The idea is simply to develop those processes which the engineer needs.

As to the amount required, the speaker had never found that he got any too much; nearly all had been of use to him; while it is not necessary for the engineer to have dexterity, he ought to know when a man is doing work well, and many technical graduates who have had good shop courses are able to do that. They can often tell a competent mechanic across the shop, tell from the way he holds his chisel or sets a tool in a machine; many of them pick it up very quickly when they go into the shops after graduation to acquire further experience in that line. It is quite difficult to draw the line closely as to where manual training should end. It is advisable to give a man a pretty thorough course while avoiding any attempt to give him manual dexterity. Few of the students have enough occasion for manual dexterity to warrant the time necessary for it, but everyone should do enough to familiarize himself with all the different processes in use in shopwork so that he can tell when a piece of work is well done. In moulding, which is a new thing this year and serves for illustration, two or three of the men had a great deal of difficulty in getting sound castings; the castings came out full of blow

holes and this was due to improper venting in every case. That particular thing is now well impressed on those men and all of them seem to understand it. One of the most troublesome things in the foundry is the lack of proper venting in the blow holes ; the work was carried that far, not to give the man any dexterity, but simply to let him fully understand the principle.

PROFESSOR J. GALBRAITH said that he was a representative of an engineering college in which no instruction was given in shopwork. From his experience he felt satisfied that the tendency in the past had been to attribute altogether too much importance to shop-work in the school training of engineering students. Of course his opinion of the value of training in shop-work must be judged with the knowledge of the fact that he had no experience in giving instruction of this kind. In the School of Practical Science, the four years of a student's time are fully occupied in work, no portion of which in the speaker's opinion could be replaced with advantage by shopwork. The proper field of the engineering college is the teaching of theory; the great advance which has been made of late years in engineering education is due to improved methods of teaching theory. It is now thoroughly recognized that instruction in theory cannot be satisfactorily given without the aid of practical work in the drafting room, laboratories and field. Concurrently with this kind of instruction, the college should give as far as possible, such practical training as may be necessary to render a student immediately useful to his employers on entering upon the practical work of the profession. If, after these objects have been prop-

erly provided for in a four years' course, there still remains time to be filled up and money to be spent, the question of introducing instruction in shopwork may be entertained. It may be granted that a better general knowledge of the use of tools may be acquired in a given time in a school where a systematic course of instruction is provided, than in an ordinary shop ; the question is whether the time may not be more usefully employed. It is necessary for success in his profession that the engineer acquire a knowledge of a large number of trades, but that knowledge is certainly not the knowledge possessed by the tradesman. Since shopwork holds its place in the curriculum not so much for its practical as for its educational value, it becomes a question whether the time which is now spent on three or four trades, might not better be spent on the single trade of pattern-making. Instruction in pattern-making cannot be given without forcing the student to make himself acquainted with a large portion of the work of a manufacturing establishment, in addition to learning the use of his tools and the manipulation of his material.

PROFESSOR THOMAS GRAY said that the amount of time devoted to practical work, in some estimates, seems exceedingly small from the point of view of the amount of time which is necessary to make an artisan. There has been a good deal of talk about making expert workmen, or giving some idea as to how to use tools. Six or seven hours a week for one year would represent about three full weeks of practical work. Imagine making an artisan in three weeks. The amount of time which Professor Galbraith speaks of as

being necessary for the degree in Toronto, is enormously greater than is considered necessary in any of the schools with which the speaker is acquainted. The shop practice given in any of the technical colleges seems not of very great consequence looked upon from the artisan point of view. It is not practicable to produce workmen in any one of the subjects. But there is another point of view from which to examine the subject. In the beginning of teaching machine design, for instance, it is a great help for the student to know what difficulties will be presented by the thing he has drawn, when he tries to make a pattern for it; to know when things are difficult to make and when they are easy. In the same way, in a machine shop, it is a great help to a man afterwards to have seen a number of things made, to have helped make them, to have made a small piece of them, to have had his attention drawn to the different parts made by others, and to have had pointed out to him the parts that are difficult to make and to be told that a certain part might have been made in another way, or altered in such a way that it could be made much more easily ; that kind of thing cannot be done in school lectures. It is possible to do a great deal of good to an engineering student in that way without attempting to produce a workman. There is not any question probably among the authorities of the best schools with regard to the question of artisan training. The educational part of the matter is the one to be kept always in view; do just as much of manual training as is of assistance in connection with that part, but beyond that let the students, if they want to become workmen after grad-

uation, become workmen by learning to work. If they require certain technical or manual experience to take charge of certain works, let them acquire it in the proper place. The workshop is the proper place to produce an artisan.

PROFESSOR STORM BULL referred to the statement previously made by himself that they had no shop-work in German technical schools. It is true that they hardly do any shopwork. The speaker did not call attention to this because he approves of it, for the contrary was the case. But it was almost put in that light in the paper. The speaker certainly approves of shopwork. He approves of laboratory work in mechanical engineering in the various lines in which it is taken up in Germany. Of course it is difficult to decide upon the limit. In the University of Wisconsin he was inclined to think they went too far in the line of shopwork. He had tried to have it cut down, but had been unable to do as much as he wanted to. There are required about nine hundred hours of shopwork during the whole course of four years. That would be the equivalent of something more than twenty weeks. That is altogether too much. At one time it was the custom to design a piece of apparatus like a small steam engine, or something of that kind, in the drafting room, and then go into the shop, make the patterns, mould and cast, and do everything necessary to finish the piece of machinery. That is a very valuable experience. The students who have graduated have said so later on. But it takes too much time. It crowds out of the course other things which ought to be attended to. If twenty

weeks is too much, it is hard to decide how much should be allowed; possibly ten weeks altogether might be enough, but the man who has charge of that kind of work is the one to settle it. Of course, the object of shopwork is not to make mechanics, and that is the reason why, in the University of Wisconsin, the rule is to refuse admission to applicants who come simply to learn shopwork, by saying that they must take three full studies besides. If they can carry three full studies, that is, three hours a day, and then take the shopwork, they are allowed to enter the University. Otherwise, not.

PROFESSOR W. M. TOWLE stated that there was a wide difference in the amount of time given to shop-work in the colleges. It varies from two hundred to nearly two thousand hours. Some of this work is what is called manual training, part of it is carried to such an extent that it becomes training for the artisan. For an engineering student, the speaker would give something more than manual training, but considerably less than what would make an artisan.

The student should learn the use the various tools and acquire some dexterity in handling them, and become acquainted with the different processes of manufacturing and handling material.

In his work as a designer and manager, he will need to understand how work is handled in the shop, how the patterns are made, how it will be molded and cast, and how it will be worked in the machine shop. If he understands these things he will avoid difficult forms of construction as far as possible, and perhaps be able to modify the design so that it can be made

easier and cheaper. An engineer should know what tools will be required in building a machine, so as to know whether it can be handled in the shop, or will have to be changed to fit the tools on hand, or be built elsewhere.

To give a student an insight into these things, he should have about eight hundred hours of shop practice in carpentry, wood-turning, pattern-making, foundry work, forging and machine-tool work. He should learn the use of the hand and machine tools, and how work should be done. While he is learning the use of tools, most of the work should be in the form of exercises after the Russian system modified to suit our requirements. After he has learned to handle the tools he should be given something to make that is of practical use, for this will keep up his interest in his work.

If the work is to be done wholly by students, it should be something of which the parts are small and can be finished in a short time. The speaker does not consider it advisable to build large work unless there are workmen to help on the larger parts, for it takes too much of the student's time at one thing, and he does not get the variety of work that he should have.

PROFESSOR J. J. FLATHER said he was struck with one or two points in Professor Schuerman's paper. One in particular reminded him of what some may have seen in one of the magazines lately about teaching engineering by "looking on." Professor Schuerman suggested that a good deal could be learned by observation, cutting down the actual number of hours of

manual training, putting more into lectures and observation of the machines and the processes of construction in the manufacture of the machines. While the speaker believed in manual training as far as it may be of value to the engineer in teaching him the elements of his profession, there is still a great deal of value in the process of observation. At the Lehigh University, with which he was connected for several years, there is a very thorough system of shop visits which is an excellent training for the engineer. The men who undertake that systematic course of observation begin in the Sophomore year, and by going through the leading establishments of the city and neighborhood, become familiar with the parts and proportions of machinery and the use of tools. In the first term of their junior year, they make a systematic visit every afternoon, from half past twelve to five o'clock, observing and noting the processes in the blacksmith shop, machine shop, foundry and pattern-room, and the men learn a good deal of engineering that cannot be taught in the college machine shop. They learn how to handle larger pieces of work than are common to the average college shop. They learn something about the time necessary to do work of that kind. There is no question about the value of this work from the standpoint of machine design. After they have had that training, when it comes time for them to carry out original designs, their work in "looking on" counts; and the experience has been that those men have an excellent idea of engineering construction,—this refers to mechanical engineers—of the adaptability of the metals for the differ-

ent parts of the machine, and of the size of parts without referring to a formula; if they use a formula and make a mistake in the decimal place, they realize it. In all these ways they have an advantage over the men who have simply been in the college machine shop, and the speaker's experience has been that these men obtain a better idea of engineering construction and engineering work than the same men would have if they simply had practice in a workshop. Probably it is the locality, the surroundings, that make it more favorable at Lehigh than it could be at any other place. At Purdue University there is a college workshop, and this is supplemented by a systematic course in observation modeled upon the same lines, but not as complete as the one which has been described as in use at the Lehigh University.

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